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COMPARISON OF SOLID ADSORBENT SAMPLING TECHNIQUES FOR VOLATILE ORGANIC COMPOUNDS IN AMBIENT AIR

by

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16. ABSTRACT

The specific objective of this study was to compare the performance of three solid adsorbents (Tenax, an experimental polyimide resin, and Spherocarb) as well as cryogenic trapping/gas chromatography for sampling and analysis of a target list of volatile organic compounds in ambient air.

A series of 14 experimental sampling runs, wherein parallel samples were collected using each of the techniques, were conducted over a one-month period. Several of the runs used audit or other reference standards as a check on method performance for known analyte concentrations.

Compared to the three adsorbent methods, cryogenic trapping/gas chromatography offered better precision and accuracy for the compounds of interest, especially when a mass selective detection system was employed. None of the three adsorbents gave optimal performance for the entire list of compounds, although in general Tenax gave the best results. Spherocarb was the best adsorbent for chloroethene (vinyl chloride), dichloromethane, and 1,1,2-trichloro-1,2,2-trifluoroethane.

The polyimide material suffered from a number of operational problems which weigh heavily against its use in ambient air sampling.

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FOREWARD

Measurement and monitoring research efforts are designed to anticipate environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina, has responsibility for: assessment of environmental monitoring technology and systems for air, implementation of agency-wide quality assurance programs for air pollution measurement systems, and supplying technical support to other groups in the Agency including the Office of Air and Radiation, the Office of Toxic Substances, and the Office of Solid Waste.

The determination of the volatile organic compounds (VOCs) in ambient air is an important and challenging problem. This report describes a study wherein various solid adsorbents as well as cryogenic trapping were evaluated for the determination of trace levels of a target list of VOCs.

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ABSTRACT

The objective of this study was to compare the results of measurement of 16 volatile organic compounds in ambient air made by four sampling techniques. These techniques are solid adsorbent sampling using Tenax®, an experimental polyimide resin, and Spherocarb®; and whole air collection in canisters followed by cryogenic trapping/gas chromatography.

A series of 14 experimental sampling runs, wherein parallel samples were collected using each of the techniques, was conducted over a one month period. Several of the runs used audit or other reference standards as a check on method performance for known analyte concentrations.

Compared to the three adsorbent methods, canister sampling followed by cryogenic trapping/gas chromatography offered better precision and accuracy for the compounds of interest, especially when a mass selective detection system was employed. None of the three adsorbents gave optimal performance for the entire list of compounds, although in general Tenax® gave the best results. Spherocarb® was the best adsorbent for chloroethene (vinyl chloride), dichloromethane, and 1,1,2-trichloro-1,2,2-trifluoroethane.

The polyimide material suffered from a number of operational problems which weigh heavily against its use in ambient air sampling.

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SECTION 1

INTRODUCTION

The Methods Development and Analysis Division of the Environmental Monitoring Systems Laboratory (EMSL) of the U. S. Environmental Protection Agency is responsible for the development and evaluation of state-of-the-art and emerging analytical techniques for the determination of organic compounds in ambient air. Recently, a priority listing of volatile organic compounds (VOCs) has been established and EMSL is focusing on further development of analytical methodology for the determination of these compounds.

In general one of two approaches, solid adsorbents or whole air collection in canisters followed by cryogenic trapping, is used to preconcentrate VOCs in ambient air. Each approach has a number of advantages and limitations. Cryogenic trapping approach has been demonstrated to provide excellent recovery and precision for a number of volatile organic compounds (1), but is somewhat inconvenient when used in the field because of the complexity and size of the apparatus. Solid adsorbents can be conveniently transported to the field for sampling and returned to the laboratory for analysis. Unfortunately none of the existing solid adsorbents show recoveries comparable to cryogenic trapping techniques for a wide range of components.

By far the most widely employed adsorbent for VOCs is Tenax® GC (2). Tenax® has the advantage of good thermal stability which allows for efficient desorption of higher boiling compounds (e.g., C-12 hydrocarbons) during the analysis step. A primary limitation of Tenax® is the low retention volume of highly volatile compounds (e.g., vinyl chloride, 1,2-dichloroethane).

In order to extend the applicability of solid adsorbent collection to more volatile compounds, EMSL has conducted development and evaluation studies for various adsorbents that could be used in place of, or in combination with Tenax®. The two most promising materials for this purpose are 1) a polyimide material formed from pyromellitic anhydride and 4,4'-diaminodiphenylsulfone

(3,4), and 2) carbon molecular sieves (CMS) sold under the trademark Spherocarb®, Carbosieve®, or Carbosphere® (5).

The specific objective of the work described in this report was to compare the performance of the three adsorbents (Tenax®, polyimide, and Spherocarb®) as well as whole air collection in canisters followed by cryogenic trapping for sampling and analysis of representative VOCs at realistic concentrations in ambient air. The list of target compounds of concern is provided in Table 1. A companion report (7) describes various aspects of the cryogenic trapping system in detail, whereas this report focuses on the results obtained using the various adsorbents compared to those obtained using cryogenic trapping techniques. A detailed assessment of the performance of each solid adsorbent for each of the target compounds is provided in the Results and Discussion section.

SECTION 2

CONCLUSIONS

The conclusions to be drawn from the study described in this report are:

1) Compared to the three adsorbent methods tested, canister sampling followed by cryogenic trapping/gas chromatography offers better precision and accuracy for the compounds of interest in this study, especially when a mass selective detection system is employed to overcome most potential interferences.

2) None of the three adsorbents evaluated gave the best performance for all of the target compounds. Tenax® gave the best performance for 3-chloropropene, trichloromethane (chloroform), 1,2-dichloroethane, 1,1,1-trichloroethane, benzene, tetrachloromethane (carbon tetrachloride), trichloroethene, tetrachloroethene, and 1,2-dimethylbenzene. Polyimide performed best only for 1,1-dichloroethene (vinylidene chloride). Spherocarb® performed best only for chloroethene (vinyl chloride), dichloromethane, and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113). Toluene gave comparable results when using Tenax® and polyimide, but lower recoveries on Spherocarb®.

3) The polyimide adsorbent has several operational difficulties which diminish its usefulness in ambient air sampling. A major artifact peak, acetonitrile, is generated if clean cartridges are stored longer than 24-48 hours before analysis. In addition, a significant amount of water

is adsorbed during sampling which leads to plugging of the chromatographic column during analysis.

4) Spherocarb® should only be used if highly volatile compounds, such as chloroethene (vinyl chloride) or dichloromethane are of interest, since several of the target compounds appear to be degraded in the sampling and analysis process for this adsorbent. High levels (artifacts) of 1,1-dichloroethene (vinylidene chloride) are formed on Spherocarb®.

5) The recovery and precision obtained for the target compounds on solid adsorbents relative to cryogenic trapping/GC is acceptable for ambient air studies. Generally, individual data points for the solid adsorbents agreed within a factor of two with the cryogenic sampling data.

6) The Volatile Organic Sampling Train (VOST) style cartridges gave low blank levels and are suggested as an alternative to the open style cartridge.

SECTION 3

RECOMMENDATIONS

On the basis of the results obtained in this study, further evaluation of the polyimide material for ambient air sampling appears to be unwarranted since a number of operational difficulties were encountered, for which no obvious solution exists. Furthermore, no significant advantages in terms of recovery of highly volatile compounds were observed, in comparison to Tenax®, when sampling ambient air.

The results of this study indicate that the use of the VOST (6) style cartridges offer low blank levels for Tenax.® Since the VOST approach uses a purge gas that passes only through the inside of this cartridge, it avoids any problems associated with the Nutech 320 thermal desorption system for Tenax® in which purge gas can pass both through and around the cartridge. Based on experience during this test, the VOST approach is recommended for ambient sampling.

SECTION 4

EXPERIMENTAL

PREPARATION OF STANDARDS

The target compounds (except for vinyl chloride) were obtained as neat liquids (>98% purity) from Eastman Kodak, Baker Chemical, or Aldrich Chemical Company. Compressed gas cylinder mixtures of the compounds were prepared by injecting predetermined amounts of each test compound into an aluminum cylinder which had been previously flushed with high purity nitrogen gas and evacuated. After injection of the neat liquid standards the cylinder was pressurized to 1200 psig with high purity air. In order to verify component concentrations an accurately measured quantity of each of the neat compounds was injected into a 17.3 cubic meter teflon-lined aluminum chamber. After equlibration a GC response factor was determined for each compound by withdrawing a known volume of air into the cryogenic trapping/GC system (1). This same system was used to analyze the gas cylinder standards and the actual concentrations were calculated using the response factors derived as described above.

Vinyl chloride was obtained from Matheson Gas Products at a concentration of 50 ppmv. A diluted (1 ppmv) cylinder standard of vinyl chloride was prepared by introducing a known pressure of the commercial standard into the aluminum cylinder described above.

National Bureau of Standards compressed gas standards for benzene (SRM 1808) and tetrachloroethylene (SRM 1805) were used to verify the accuracy of the compressed gas mixture for these two components. In all cases the values determined from the GC analysis agreed within 20% of the value calculated from the volume of liquid injected and cylinder pressure. The concentrations of components in the calibration cylinder are listed in Table 1.

In addition, an audit cylinder was provided by EPA, without disclosure

TABLE 1. LIST OF TARGET COMPOUNDS

Compound	Concentration in Calibration Cylinder, µg/L[a]
Chloroethene (Vinyl chloride)	2.58
Acrylonitrile	1.30
1,1-Dichloroethene (Vinylidene chloride)	1.70
Dichloromethane (Methylene chloride)	1.33
3-Chloropropene (Allyl chloride)	1.94
Trichlorotrifluoroethane (Freon 113)	3.41
Trichloromethane (Chloroform)	2.67
1,2-Dichloroethane	2.42
1,1,1-Trichloroethane (Methyl chloroform)	2.97
Benzene	1.47
Tetrachloromethane (Carbon tetrachloride)	3.62
Trichloroethene	2.69
Toluene	1.77
Tetrachloroethene (Perchloroethylene)	3.39
Chlorobenzene	2.20
1,2-Dimethylbenzene (o-xylene)	2.04

a. At 25°C and 1 atmosphere

of the actual concentration. Component identities and measured concentrations of this mixture were determined and are included in this report.

POLYIMIDE RESIN PREPARATION

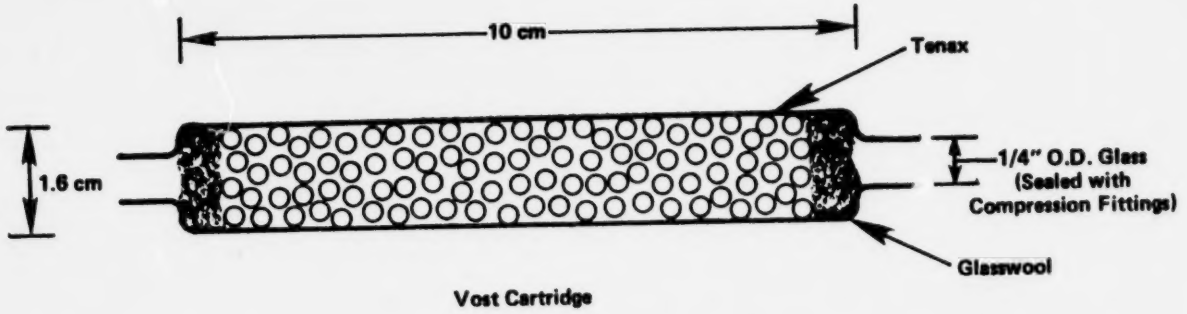
Four thirty-gram batches of polyimide resin were prepared as previously described (4). The material was processed through a series of sieves to obtain a 212-590 μm particle size fraction (approximately 30-70 mesh). Various physical properties of each batch were determined and then a portion of each batch was used to prepare adsorbent cartridges for use in the methods comparison study. The molecular weight (Mw) for each resin batch was determined by solution viscosity on the precursor polyamide-acids. Thermal stability was determined by thermogravimetric analysis (20°C/minute scan rate to 700°C) under a nitrogen atmosphere. Surface area was determined by the BET nitrogen adsorption technique using a titanium dioxide (10 square meters per gram surface area) reference standard. A Tenax® GC sample which had been previously characterized was also used as a check on accuracy.

SAMPLING CARTRIDGE PREPARATION

Tenax® GC (60/80 mesh) was purchased from Applied Sciences. Prior to packing into sampling cartridges the Tenax® GC and polyimide material was extracted in a Soxhlet apparatus with methanol followed by pentane, each for 24 hours (approximately 10 cycles/hour), and dried in a vacuum oven at room temperature using a water aspirator. The clean material was stored in a sealed glass jar having a teflon-lined cap until used. Spherocarb® was purchased from Foxboro/Analabs and was packed into sampling cartridges without prior extraction.

Tenax® GC and polyimide adsorbents were packed into glass cartridges as described for the Volatile Organic Sampling Train (VOST) system developed by EPA for stack sampling (6). Another set of Tenax® cartridges were prepared by EMSL/U.S. EPA and analyzed by that laboratory according to established standard operating procedures (8). The cartridge geometries for these two designs are shown in Figure 1. The EPA sampling and analysis system is essentially the same as has been described in the literature (2).

Spherocarb® cartridges were 0.25 inch o.d. x 3 inch long stainless



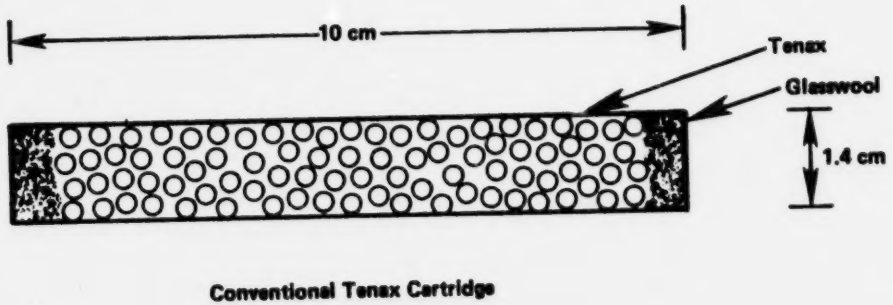


Figure 1. Diagram of conventional and VOST style Tenax® cartridges.

steel cartridges containing 0.4 grams of adsorbent, held in place with glass wool plugs at each end. The ends of the cartridge are sealed using 0.25 inch Swagelok® fittings. This cartridge design has been described in the literature (5).

Within 24 hours before sampling the cartridges were further purified by heating under a 50 mL/minute helium purge stream. The helium stream was passed through a three stage purifier consisting of a catalytic oxygen scrubber, Drierite® drier, and activated charcoal. For initial use all cartridges were desorbed for 48 hours. Polyimide and Tenax® GC were heated to 275°C whereas Spherocarb® was heated to 450°C. For reuse Spherocarb® was desorbed for 30 minutes and polyimide and Tenax® were desorbed for 16 hours.

All cartridges were stored in a one-gallon metal can containing a layer of charcoal in the bottom when not being used for sampling or analysis.

SAMPLING PROCEDURE

Sampling Manifold

In order to obtain a uniform air sample for each of the sampling and analysis techniques, a glass manifold (Ace Glass Co.) was used as shown in Figure 2. The manifold contained a five-foot sampling inlet which extended through the roof of the mobile laboratory. Inside the laboratory the inlet was connected sequentially to a 76 mm glass filter holder, a 3 ft mixing chamber, and a 3 ft sampling chamber. A variable speed pump and dry test meter were used to maintain a flow of 50 L/min through the manifold. A rotameter was placed into the system to provide a visual check of the flow rate. A quartz fiber filter (Quast 2500) was inserted into the filter holder to remove particles from ambient air. The mixing chamber was modified at Battelle to permit the spiking of ambient air with known amounts of air from a calibration cylinder (Table 1). To verify that complete mixing occurred prior to the sampling chamber, NO (1.0 ppm) was injected into the mixing chamber via the gas dilution system. An NO analyzer was used to probe the various sampling ports to assure complete mixing.

For normal sampling periods incoming ambient air was spiked with a calibration mixture (50.0 mL/min) from the gas dilution system. To operate

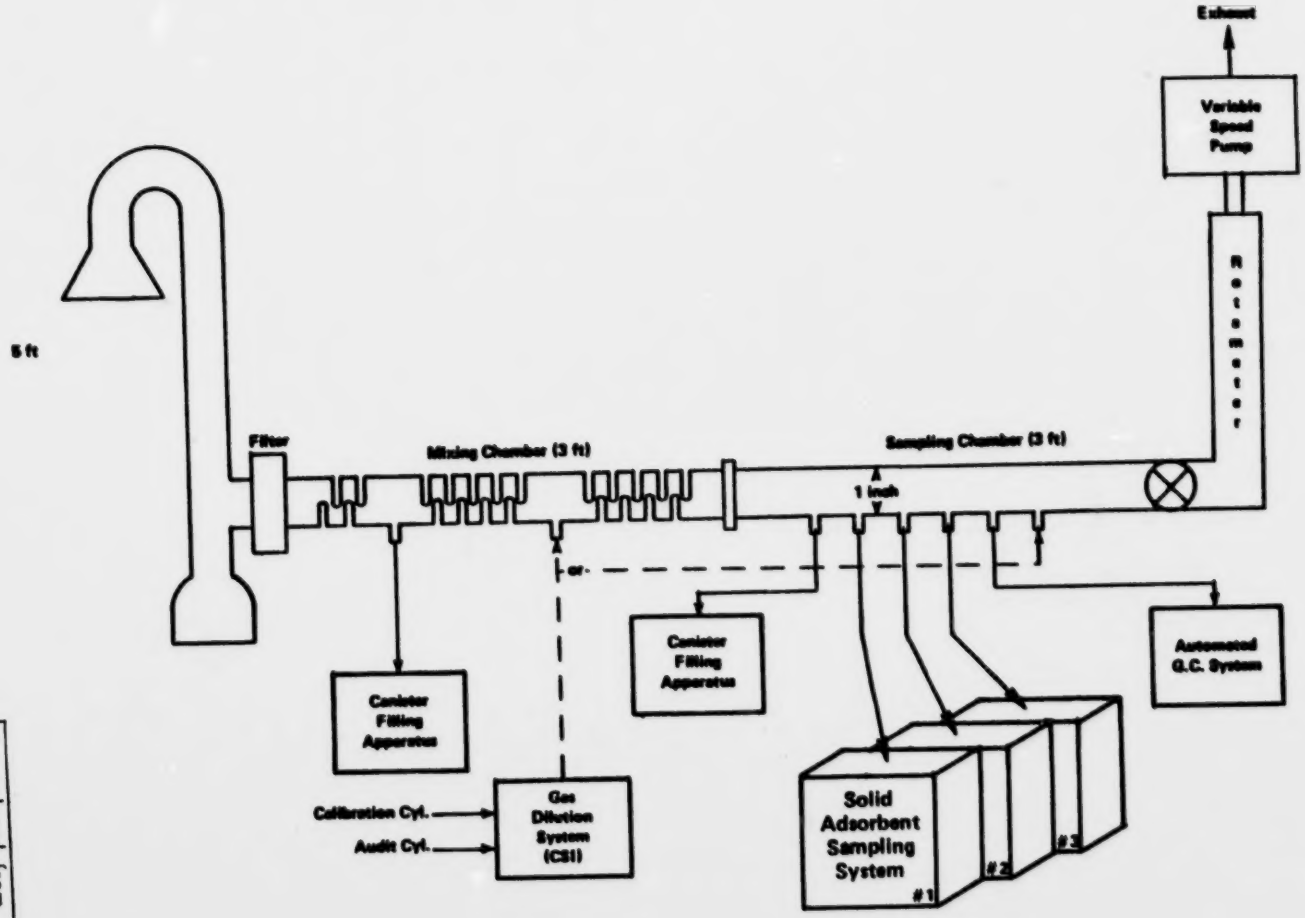


Figure 2. Sampling manifold.

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the gas dilution system a flow of ultra-zero air (1.00 L/min) was also required. For several of the sampling periods calibration or audit mixtures were backflushed through the manifold to generate known calibration mixtures. To carry out this task the gas dilution flow from the CSI unit was diverted from the mixing chamber to the sampling chamber. Likewise the pump and ball valve were shut off so that the flow exited through the mixing chamber. During these tests the calibration/audit flow was 50.0 mL/min while the ultra-zero air flow was maintained at 5.00 L/min (0.0099 dilution).

Sampling Protocol

Thirteen test runs were carried out at the field site. Ten sampling runs were made with spiked ambient air while the remaining three runs involved the injection of calibration mixtures (two with the audit cylinder/ one with Battelle's calibration cylinder). The test runs were usually started at 1:00 p.m. and each lasted two hours. The automated GC system collected two fifty minute integrated samples during this time (7). The operational procedure for these sampling systems follows.

Canister Filling Apparatus

Two 6-liter stainless steel canisters (Demaray Scientific Instrument, Ltd., Pullman, WA) were used for collecting integrated whole air samples for later analysis using the cryogenic trapping system. Prior to sampling, each canister was sequentially filled (15 psig) and evacuated (25" Hg) five times using ultra zero air as the flushing gas. After the fifth evacuation the canister was sealed, transferred to a higher vacuum system and pumped down to 1.0 torr. A liquid nitrogen trap was utilized in this system to prevent organics originating in the pump oil from back-streaming into the can. Following the final evacuation each canister was connected to the appropriate filling apparatus in preparation for sampling. This operation and the subsequent cryogenic/GC analysis procedure is described fully in a companion report (7).

Solid Adsorbent Collections

Adsorbent tubes were collected for analysis using the system shown in Figure 3. Each mass flow controller was adjusted so that the desired nominal sample volumes were collected over a 2-hour period. The adsorbent

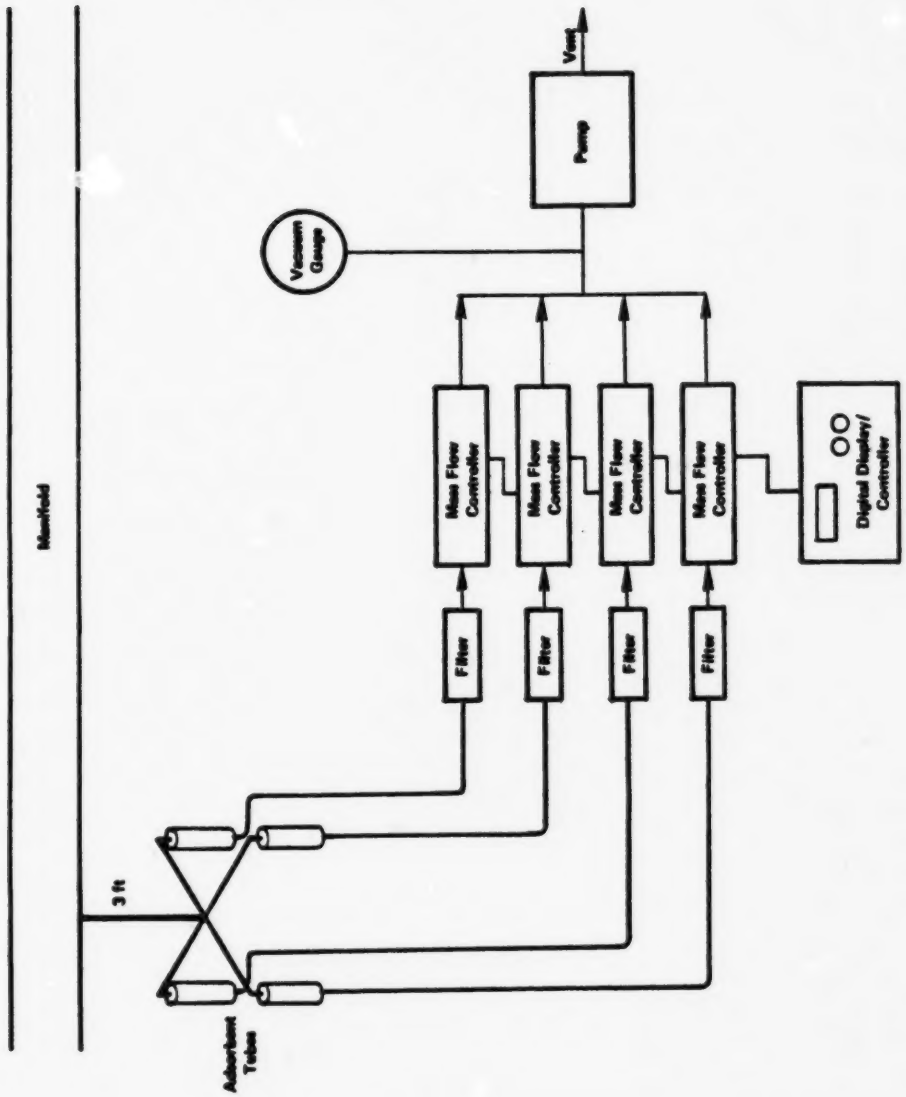

Figure 3. Solid adsorbent sampling system.

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tubes were leak checked immediately before sampling by sealing the inlet line and initiating sample collection (i.e., pump on). A leak-free system was indicated by a zero reading on the mass flow controller. Sample blanks were obtained by removing a blank cartridge from its storage container, placing it in line, and repeating the leak check procedure. The blank was then immediately returned to its container.

Samples collected for analysis at Battelle were stored capped in charcoal-containing one-gallon metal cans until analyzed (within 48 hours of collection).

All EPA/EMSL samples and blank adsorbent tubes were housed in screw-cap culture tubes (Teflon sealed). When not in use, the culture tubes were stored in sealed metal cans containing activated charcoal. Because the outer surface of the Tenax® adsorbent tubes were also desorbed into the analytical instrumentation, special nylon gloves were utilized during all sample handling procedures. Samples were shipped to and from Battelle by air express.

GC/MS Analysis

The system used for GC/MS analysis of Spherocarb® cartridges is shown in Figure 4 (5). Unless otherwise indicated, all lines in the apparatus were maintained at 150°C. The system used for analysis of Tenax® and polyimide cartridges was identifical except that a tube furnace was used to heat the cartridges to the desired desorption temperature. The stainless steel Spherocarb® cartridges were heated using a built-in thermocouple wire heater as described elsewhere (5). Prior to analysis the Spherocarb cartridges were purged with dry air at 200 mL/minute for ten minutes (in the same direction as sample flow) to remove moisture. In the analysis process the Spherocarb® cartridge was heated (over a 4-5 minute period) to 375° $\pm$ 15°C under a helium purge flow of mL/minute with the cryogenic loop held at nitrogen temperature. After cartridge desorption the 6-port valve was placed in the "inject" position and the cryogenic loop rapidly heated to 150°C over a 30-40 second period. In this process the analytes were flashed onto the head of the GC column, which was maintained at -70°C for two minutes after sample injection, and subsequently was heated to 150°C at 8°/minute. Mass spectral data acquisition is initiated four minutes after injection.

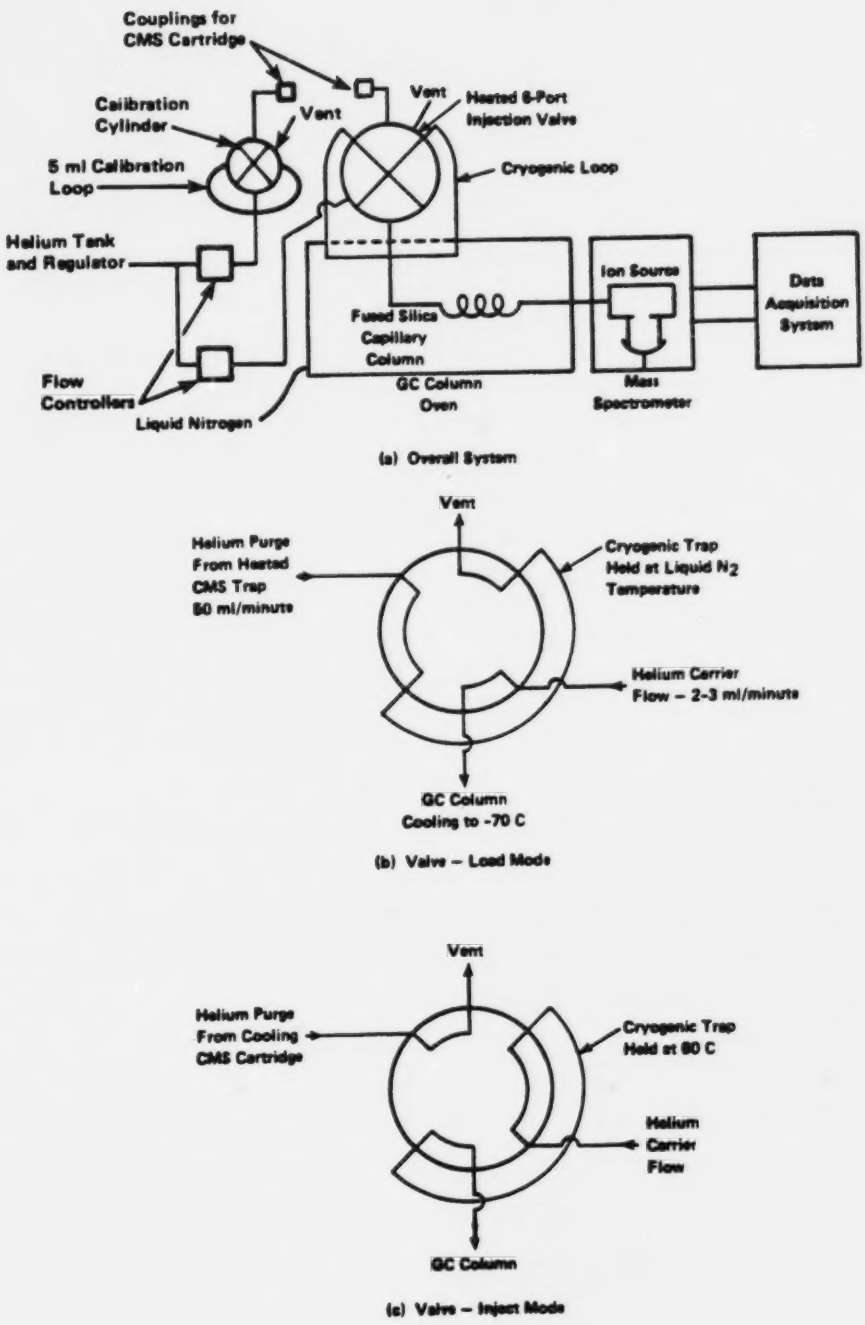

Figure 4. GC/MS analysis system for Spherocarb® cartridges.

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An Extranuclear dual EI/CI mass spectrometer interfaced to a Hewlett Packard 5730 capillary column GC system was employed in this work. Ionization was 70 eV electron impact and the scan range was 30-300 amu at 0.6 seconds/scan. A 50 meter Hewlett Packard SE-30 crosslinked fused silica, wide bore, thick film GC column was used. Components were quantified by comparing the integrated ion intensity for a characteristic "quantification" ion for the sample to that of a standard, prepared in an aluminum cylinder. Known quantities of the compressed gas standard were injected onto the system using a 6-port valve upstream of the cartridge desorption module (Figure 4), with a stainless steel union installed in place of the absorbent cartridge. Conditions for the analysis of Tenax® and polyimide cartridges were identical except that these materials were desorbed at 240°C using the VOST oven (6).

SECTION 5

RESULTS AND DISCUSSION

POLYIMIDE RESIN PREPARATION AND CHARACTERIZATION

The quantities obtained and physical properties of each batch of polyimide resin are shown in Table 2. The molecular weights obtained (3200-3800) are towards the lower end of the range of those obtained for the same resin material prepared under an earlier work assignment (4). The reason for the lower molecular weight is believed to be a slightly lower purity for the diaminodiphenylsulfone (DADS) monomer. Although the same monomer purification procedure was used for both studies, differential scanning colorimetry of the monomer used in this study indicated the presence of a small amount of a single impurity which was not present in the high purity monomer used previously. Nevertheless the monomer used in the present work still was greater than 99.9% pure.

Thermogravimetric analysis showed the resins to be quite stable up to 250°C, with a slowly accelerating weight loss above that temperature. In preliminary sampling and analysis experiments higher desorption temperatures (275°C) were found to be necessary to adequately purify the resins. This conditioning temperature caused some degree of shrinkage in the resin cartridge, necessitating addition of additional glass wool to maintain a tightly packed bed.

The surface areas of the resins were unexpectedly high, 64-73 square meters/gram, compared to the earlier study in which values in the range of 32-38 were obtained. The validity of these data was substantiated by the reanalysis of both a reference titanium oxide and a previously measured polyimide resin sample. The same values, 10 and 34 square meters/gram respectively, were obtained as in the earlier study. The reason for the higher surface areas obtained in the present work is not known. Possibly it is related to careful attention to procedure in the polymerization and

TABLE 2. PHYSICAL PROPERTIES OF FOUR BATCHES OF POLYIMIDE RESIN

Batch Number	Quantity Grams	Molecular Weight, Mw	Thermal Stability, C	Surface Area, M^2/gm
1	28.4	3,400	250	70
2	29.2	3,600	250	73
3	30.2	3,800	250	64
4	31.6	3,200	250	67

polymer product (powder) recovery steps, especially the latter. However this could only be determined by carrying out a series of polymerization and product recovery experiments in which the procedures are systematically varied to determine the effect on the products. Such a study was not possible within the time and resources available on the work assignment. The material obtained was believed to be sufficiently uniform from batch to batch, in terms of physical properties, to fulfill the methods comparison objective of this study.

For laboratory evaluation of the resins, the four batches were extracted with methanol and then pentane for 16 hours (each solvent). After pentane extraction the resins were dried overnight at 30°C under vacuum (water aspiration). Two "VOST" style cartridges of each batch of resin were prepared (1.5 grams/cartridge) and desorbed at 240°C for 24 hours under a helium flow of 50 mL/min. One cartridge from each batch was analyzed by GC/FID using the following conditions:

Desorption temperature - 150°C
Desorption time - 10 minutes
Desorption flow - 50 mL/min helium
GC column - 50 meter methyl silicone fused silica, wide bore, thick film, Hewlett-Packard
Temperature program - -70°C to 150°C at 8°C/min.

Although no substantial differences were observed between batches, the data obtained indicated that additional desorption time was required to adequately remove the pentane extraction solvent. Therefore all of the cartridges were desorbed for an additional 48 hours at 240°C. This amount of desorption provided adequate blanks, with Batch Number 3 yielding the cleanest blank. All subsequent work was conducted using this batch of resin. Unfortunately after storing the cartridges for more than 24 hours a large artifact peak, later determined to be acetonitrile, was observed in the blank; Figure 5 demonstrates this result. The reasons for the presence of acetonitrile are not clear since this material is not used in the resin preparation or purification procedures.

In order to check desorption efficiencies for the compounds, a twenty-five milliliter sample of the compressed gas containing the target compounds

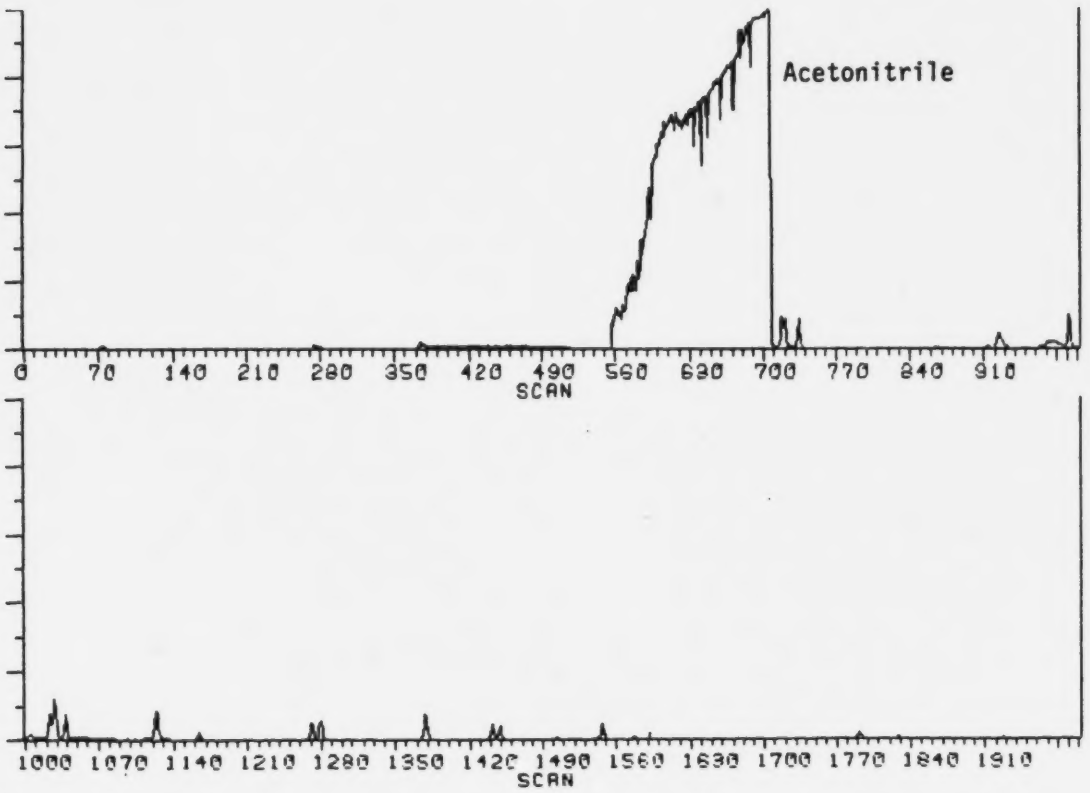

Figure 5. Chromatogram demonstrating acetonitrile artifact peak

was injected onto each of three polyimide cartridges using a gas injection loop with a helium flow of 50 mL/minute. This flow was maintained for 10 minutes. The cartridge was then desorbed (with flow in the reverse direction) using the conditions described above. The results obtained are shown in Table 3. As shown in this table, good recoveries were obtained for all of the compounds except vinyl chloride (76 percent) and Freon 113 (71 percent).

Another set of experiments was conducted to determine the recovery of compounds present at low concentrations in a flowing air stream. A CSI dynamic dilution system was employed using the standard compressed gas cylinder and Aadco air as the inlet streams. The Aadco air stream was set at 3 liters/minute and the compressed gas stream at 7.5 mL/minute, yielding an outlet concentration of approximately 1.2 ppbv for each analyte. This stream was sampled at 0.5 liters/minute through three polyimide cartridges for 20, 40, and 80 minutes, respectively. The cartridges were then analyzed as described above. The data for these analyses are shown in Table 4. In view of the low recovery observed for the high boiling compounds, especially 1,2-dimethylbenzene, the desorption temperature was increased to 200°C for the 40 and 80 minute (20 and 40 liter) collections.

The data in Table 2 indicate that even with a 40 liter sample volume good recovery can be obtained for vinylidene chloride and compounds of similar volatility. However, recovery of the high boiling compounds, such as 1,2-dimethylbenzene, was not good even at the 200°C desorption temperature. Increasing the desorption temperature to 270°C did not yield significantly better recovery for 1,2-dimethylbenzene.

For all subsequent studies an initial 48-hour cartridge purification at 275°C and sample desorption temperature of 240°C was employed.

METHODS COMPARISON STUDY FOR AMBIENT AIR

In order to compare the performance of the various methods for sampling volatile organic compounds in ambient air, a series of parallel sampling experiments were conducted during the summer of 1984 in the parking lot at Battelle. Details of the sampling protocol are provided in the Experimental section, as well as in a companion report (7). The individual

TABLE 3. ANALYTICAL RECOVERY DATA FOR POLYIMIDE (DADS) TRAPS SPIKED DIRECTLY

Compound	Amount Injected, ng	Percent Recovery	Standard Deviation (Triplicates), %
Chloroethene	32	76	12
Acrylonitrile	38	107	2
1,1-Dichloroethene	55	88	8
Dichloromethane	42	99	8
3-Chloropropene	56	89	6
Trichlorotrifluoroethane	102	71	18
Trichloromethane	72	95	11
1,2-Dichloroethane	62	112	30
1,1,1-Trichloroethane	75	90	18
Benzene	38	111	32
Tetrachloromethane	95	82	17
Trichloroethene	72	109	31
Toluene	46	97	3
Tetrachloroethene	88	100	17
Chlorobenzene	61	98	6
1,2-Dimethylbenzene	56	81	3

TABLE 4. ANALYTICAL RECOVERY DATA FOR POLYIMIDE (DADS) TRAPS SAMPLING SPIKED HIGH PURITY AIR

Compound	Percent Recovery		
	10 Liter Sample[a]	20 Liter Sample[b]	40 Liter Sample[b]
Chloroethene	70	65	25
Acrylonitrile	40	36	44
1,1-Dichloroethene	100	85	81
Dichloromethane	100	78	89
3-Chloropropene	92	80	88
Trichlorotrifluoroethane	54	44	20
Trichloromethane	100	70	89
1,2-Dichloroethane	64	53	67
1,1,1-Trichloroethane	82	80	77
Benzene	74	61	76
Tetrachloromethane	81	76	65
Trichloroethene	66	49	69
Toluene	42	35	48
Tetrachloroethene	43	33	44
Chlorobenzene	25	49	51
1,2-Dimethylbenzene	12	18	20

a. Desorption temperature 150°C
b. Desorption temperature 200°C to improve recovery of high boiling compounds.

sampling runs conducted are listed in Table 5. As indicated in this table, Run Numbers 4 and 11 were clean air experiments using an audit cylinder supplied by EPA, and Run Number 5 was a similar run using the calibration cylinder described in the Experimental section. Results for the audit and calibration cylinders are discussed in later portions of the report, whereas this discussion will focus on the method performance sampling ambient air.

For each sampling run a series of four Tenax® samples, (nominally 5, 10, 10, and 20 liters respectively), two polyimide samples (nominally 10 liters each) and two Spherocarb® samples (nominally 10 liters each) were collected from a sampling manifold over a two-hour time period. To ensure detectability for all of the target compounds, a trace quantity of a gaseous standard containing the target compounds was spiked into the manifold ahead of the adsorbent sampling ports. Simultaneously, canister samples for later analysis by cryogenic trapping/GC were collected both upstream and downstream of the point of introduction of the compressed gas standard.

All of the data obtained in these experiments are provided in the Appendix. These data have been corrected for blank contribution, which was negligible in most cases. Blank data for Tenax® from both Battelle and EPA analysis are shown in Table 6. In no instance did the blank level for the Battelle analysis approach the concentration observed in the samples. The comparison of blank data from Battelle and EPA is discussed later in this section of the report.

In order to compare the performance of the various methods for ambient air, the apparent recovery of the adsorbent samples for each run, relative to the cryogenic trapping value was calculated. Use of the cryogenic trapping value was considered to be most appropriate since this technique generally agreed best with the theoretical concentration, and gave better precision than did any of the adsorbent techniques. The performance of the cryogenic trapping/GC system is described in more detail in the companion report (7). Most of the values used for the cryogenic trapping data were obtained using the mass selective detector, since this detection system was less subject to potential interferences. However, the toluene and 1,2-dimethylbenzene values were obtained using FID due to limitations on the number of ions which could be monitored using the mass selective detector.

Comparative data for the various adsorbents is summarized in Table 7. The individual data points used in these calculations are presented in

TABLE 5. LIST OF SAMPLING RUNS

Run #	Sampling Date	Description
1	07/12/84	Trial Run, Ambient Air
2	07/17/84	Ambient Air
3	07/19/84	Ambient Air
4	07/20/84	Audit Cylinder
5	07/24/84	Calibration Cylinder
6	07/26/84	Ambient Air
7	07/27/84	Ambient Air
8	07/30/84	Ambient Air
9	07/31/84	Ambient Air
10	08/02/84	Ambient Air
11	08/03/84	Audit Cylinder
12	08/06/84	Ambient Air
13	08/07/84	Ambient Air
14	08/09/84	Ambient Air

TABLE 6. DATA FOR BLANK TENAX® CARTRIDGES, ng/cartridge[a]

Compound	EPA (N=6)		Battelle (N=5)	
	Highest Value	Average	Highest Value	Average
Dichloromethane	NR	NR	58	14
3-Chloropropene	NR	NR	ND	ND
1,1,2-Trichloro-1,2,2-trifluoroethane	NR	NR	8.3	5.5
Trichloromethane	38	26	0.44	0.1
1,2-Dichloroethane	NR	NR	ND	ND
1,1,1-Trichloroethane	90	62	5.0	1.9
Benzene	93	76	5.6	1.9
Tetrachloromethane	ND	ND	ND	ND
Trichloroethene	ND	ND	3.3	0.7
Toluene	116	50	8.1	2.5
Tetrachloroethene	ND	ND	ND	ND
Chlorobenzene	ND	ND	8.6	1.7
1,2-Dimethylbenzene	NR	NR	3.7	1.5

ND = Not detected in any blank.
NR = Not reported.

a. In some cases EPA blank samples may have been subjected to considerable temperature cycles resulting from air shipment and airport storage prior to analysis. These blank samples also were not handled according to EPA procedures (see text for discussion).

TABLE 7. PERFORMANCE DATA FOR SOLID ADSORBENTS RELATIVE TO CRYOGENIC TRAPPING

Compound	Tenax Breakthrough Volume[a], Liters/Cartridge	Average Recovery Relative To Cryogenic Trapping, %		
		Tenax	Polyimide	Spherocarb
Chloroethene	0.8	--[b]	--[b]	73(23)[d]
1,1-Dichloroethene	Not Given	--[b]	52(28)	410(260)
Dichloromethane	4	83(21)	86(31)	85(12)
3-Chloropropene[c]	6	87(35)	140(68)	29(14)
1,1,2-Trichloro-1,2,2, -Trifluoroethane	Not Given	39(25)	17(14)	69(30)
Trichloromethane[c]	13	100(36)	75(25)	65(17)
1,2-Dichloroethane[c]	18	100(15)	65(15)	75(14)
1,1,1-Trichloroethane[c]	9	130(42)	51(14)	46(10)
Benzene	27	100(18)	130(34)	140(63)
Tetrachloromethane[c]	13	110(37)	53(19)	29(9)
Trichloroethene	28	112(26)	100(33)	90(33)
Toluene	122	70(19)	70(17)	43(8)
Tetrachloroethene	106	88(27)	78(30)	72(30)
Chlorobenzene	249	78(35)	57(21)	53(19)
1,2-Dimethylbenzene	334[e]	55(21)	40(15)	20(7.9)

a. Data from Reference 2 at 90°F
b. No meaningful data obtained
c. Low volume (nominally 5 liters) Tenax value used for these compounds. Medium volume (nominally 10 liters) Tenax value used for all other compounds.
d. Value in parentheses is standard deviation for all sampling runs, except for audit and calibration cylinder sampling.
e. Value for ethylbenzene.

Figures 7-21. A typical GC/MS chromatogram is shown in Figure 6. For poorly retained compounds the low volume Tenax® sample (nominally 5 liters) was used, whereas for better retained compounds the duplicate 10 liter Tenax® samples were used for these calculations.

As expected, none of the adsorbents performed best for all of the target compounds. Tenax® performed best for 3-chloropropene (allyl chloride), trichloromethane (chloroform), 1,2-dichloroethane, 1,1,1-trichloroethane, benzene, tetrachloromethane (carbon tetrachloride), trichloroethene, tetrachloroethene (perchloroethylene), and 1,2-dimethylbenzene (o-xylene). Tenax® and polyimide gave essentially identical results for toluene. As expected, on the basis of breakthrough volume data, Tenax® gave essentially no recovery for chloroethene (vinyl chloride) and 1,1-dichloroethene (vinylidene chloride).

Polyimide performed better than both Spherocarb® and Tenax® only for 1,1-dichloroethene, although only 55 percent recovery and 28 percent standard deviation were obtained. Polyimide gave essentially no recovery for chloroethene, in spite of the good recovery obtained for this compound in high purity air sampling (Tables 3 and 4). Polyimide also gave disappointingly low and variable recovery for 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), 1,1,1-trichloroethane, and tetrachloromethane. An operational problem which weighs heavily against the use of this material for ambient air sampling is the adsorption of a significant amount of moisture onto the adsorbent. The presence of water in the matrix led to the chromatographic column plugging during virtually all of the ambient air sampling runs (plugging of the column was not observed for any dry air runs using the audit or calibration cylinders). A similar phenomenon is observed for Spherocarb®. However, in that case the cartridge is prepurged with dry air, at room temperature, prior to analysis to remove adsorbed moisture. A similar approach was not successful in eliminating the problem for the polyimide material, indicating that the adsorbed moisture is difficult to desorb due to kinetic or thermodynamic factors.

Spherocarb® gave the best results of the three resins only for chloroethene, dichloromethane, and 1,1,2-trichloro-1,2,2-trifluoroethane. Spherocarb® gave extremely poor results for 1,1-dichloroethene, 3-chloropropene, 1,2-dimethylbenzene, and tetrachloromethane. In the case of

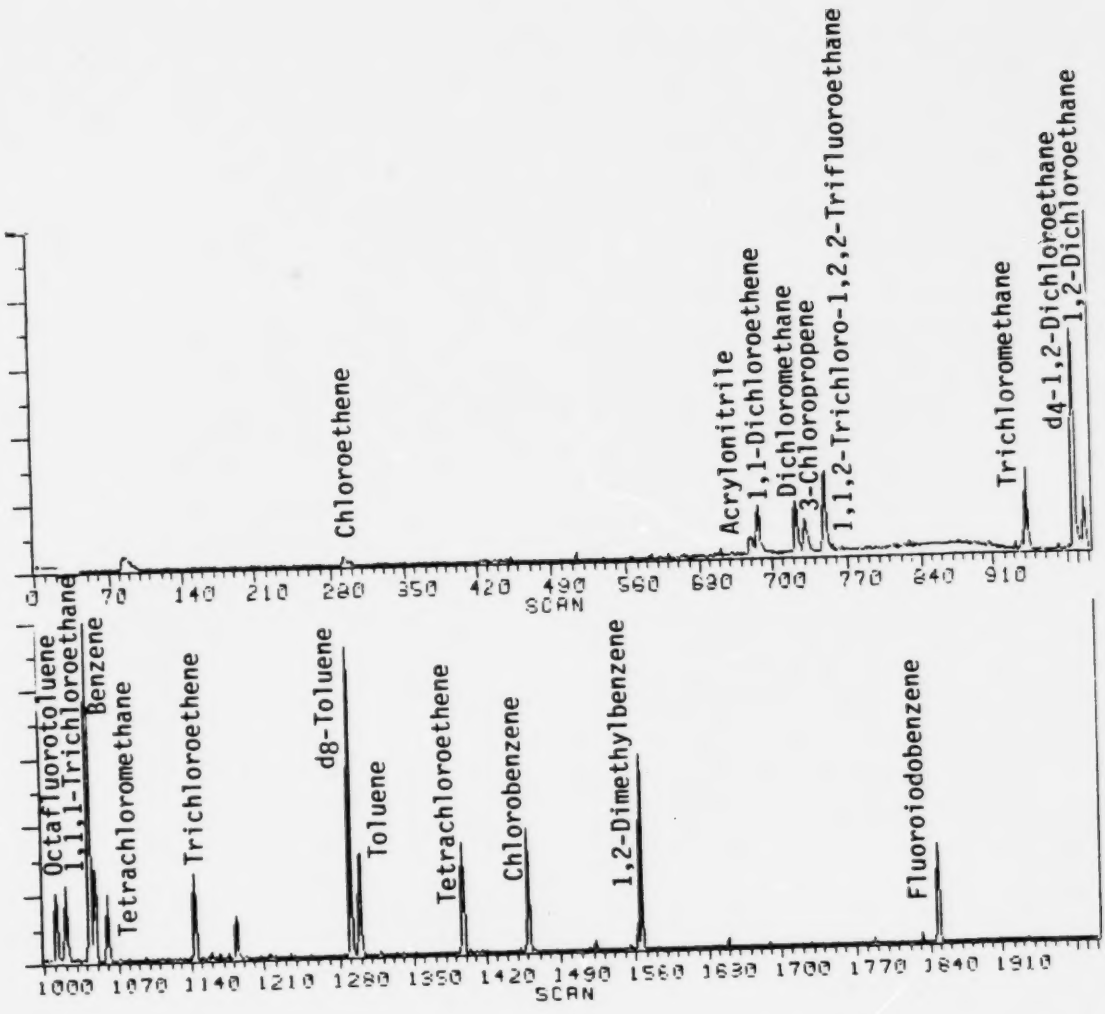

Figure 6. GC/MS reconstructed gas chromatogram for calibration standard (10-25 ng/compound).

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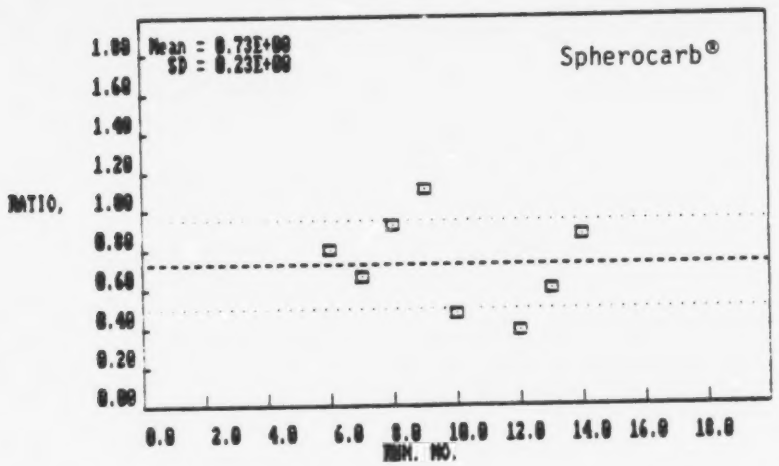

Figure 7. Scatterplot of chloroethene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

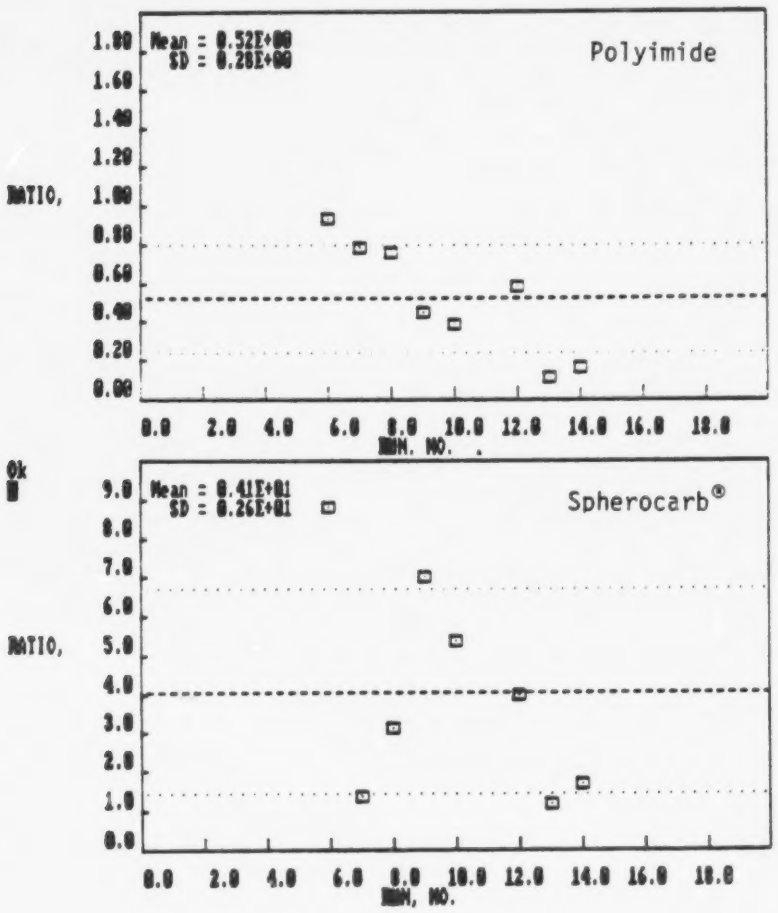

Figure 8. Scatterplot of 1,1-dichloroethene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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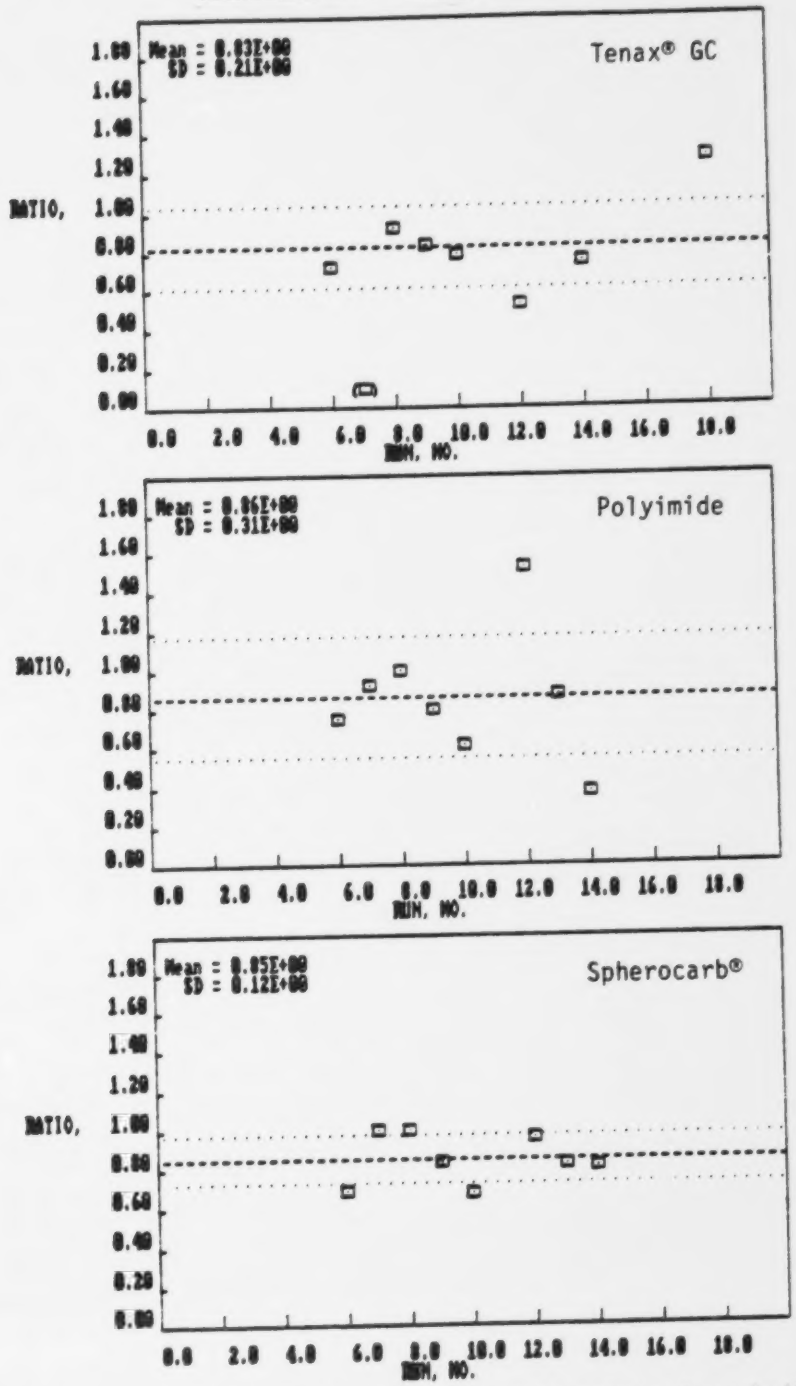

Figure 9. Scatterplot of dichloromethane data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

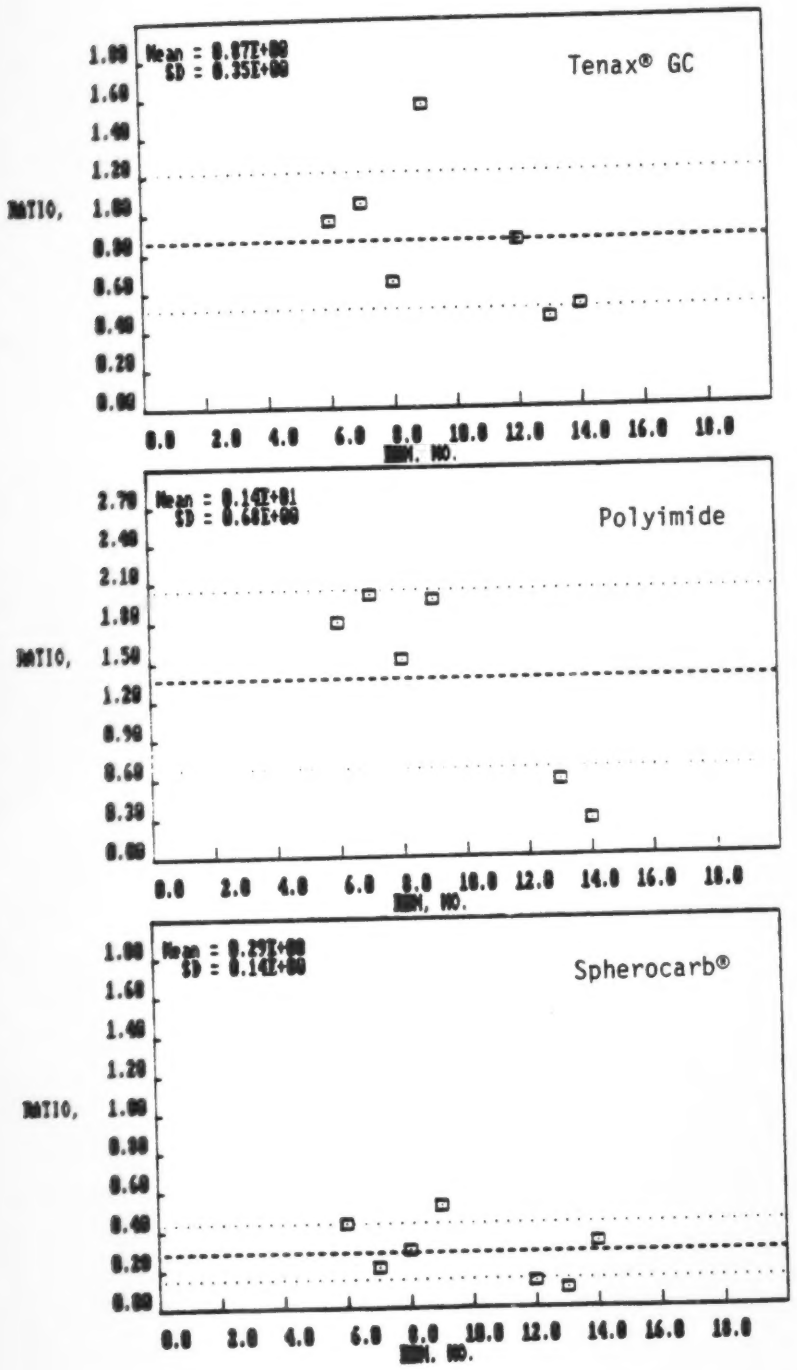

Figure 10. Scatterplot of 3-chloropropene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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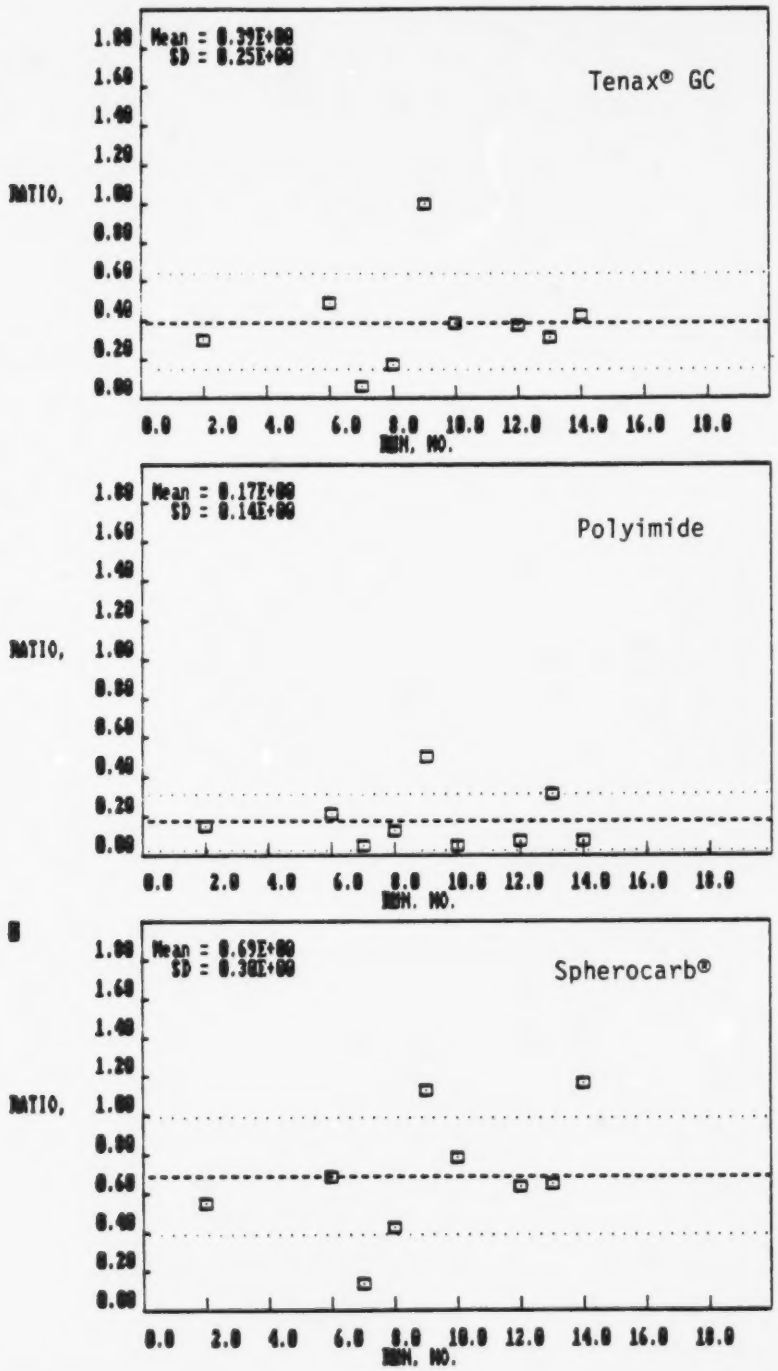

Figure 11. Scatterplot of trichlorotrifluoroethane data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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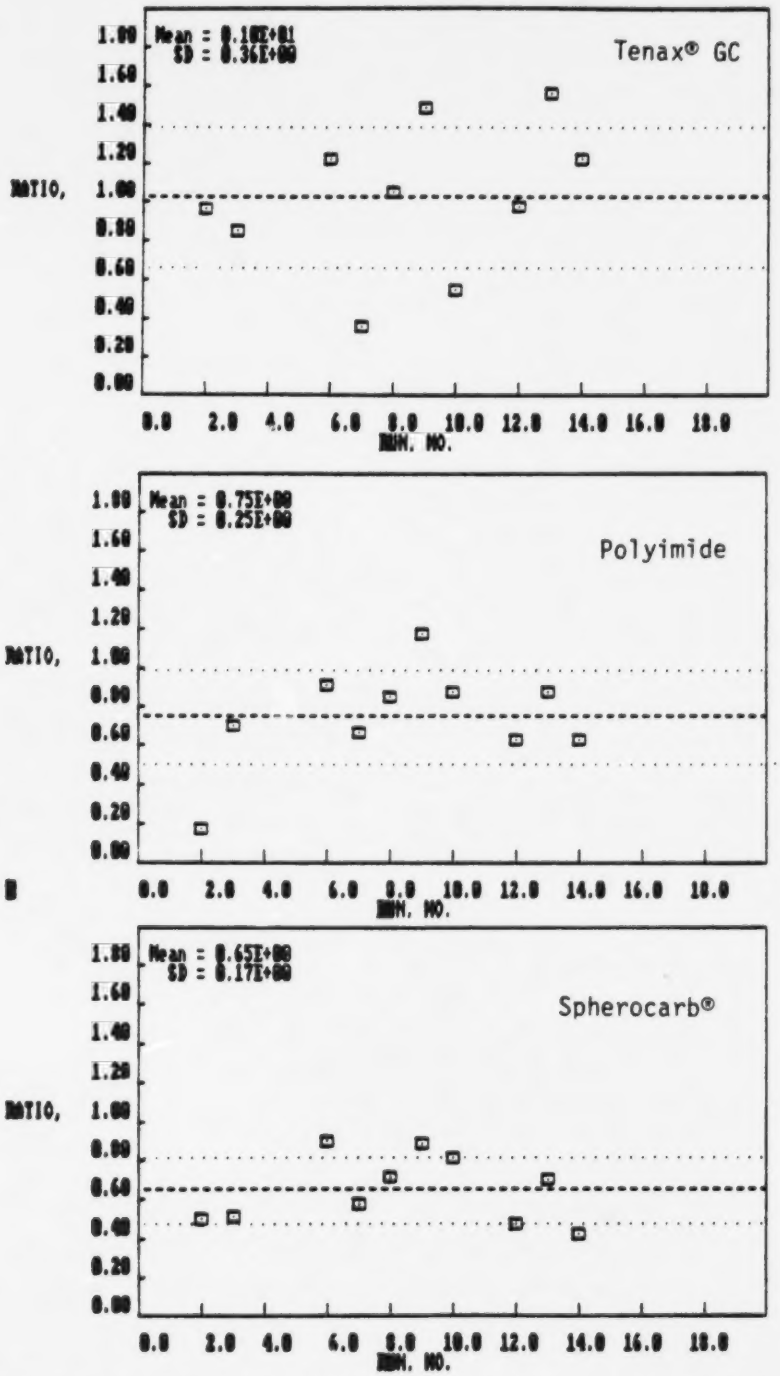

Figure 12. Scatterplot of trichloromethane data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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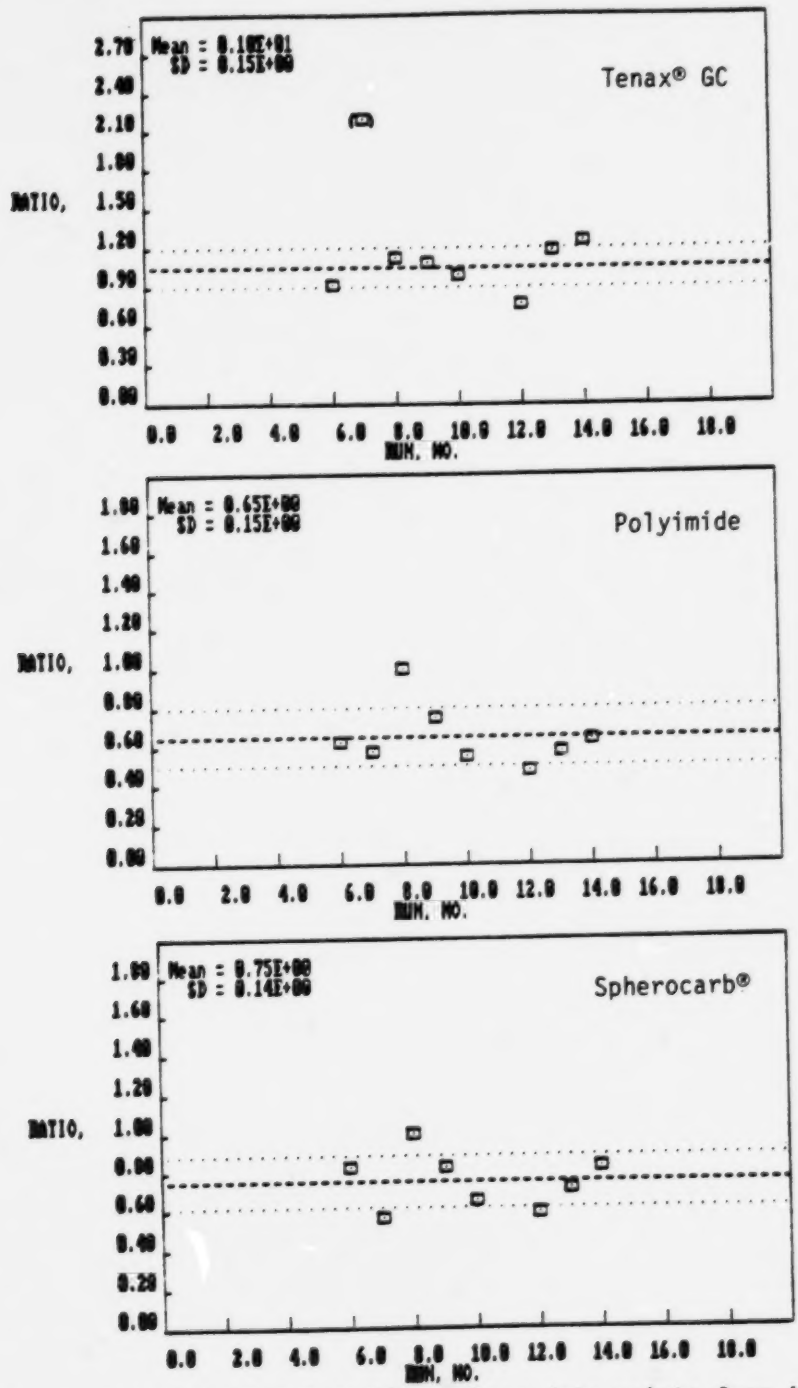

Figure 13. Scatterplot of 1,2-dichloroethane data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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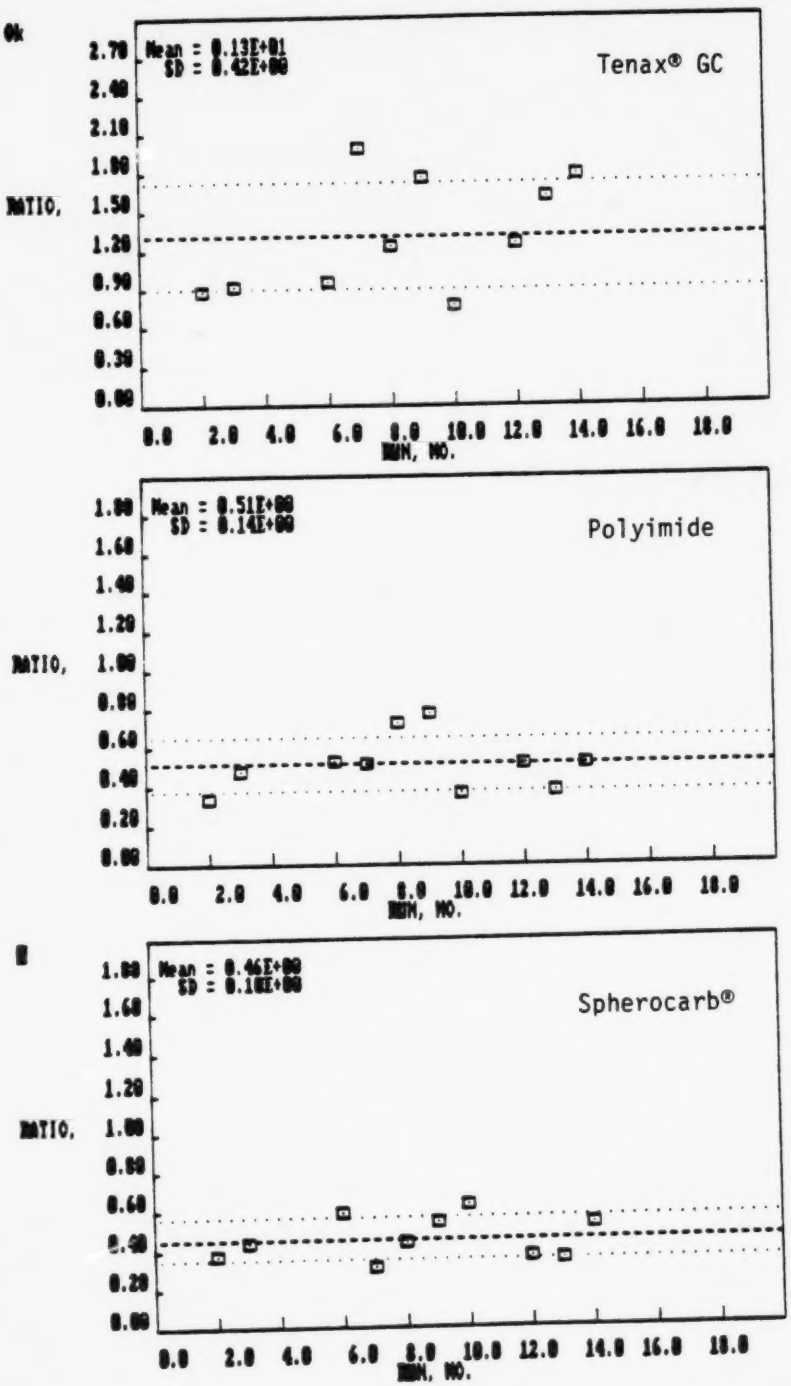

Figure 14. Scatterplot of 1,1,1-trichloroethane data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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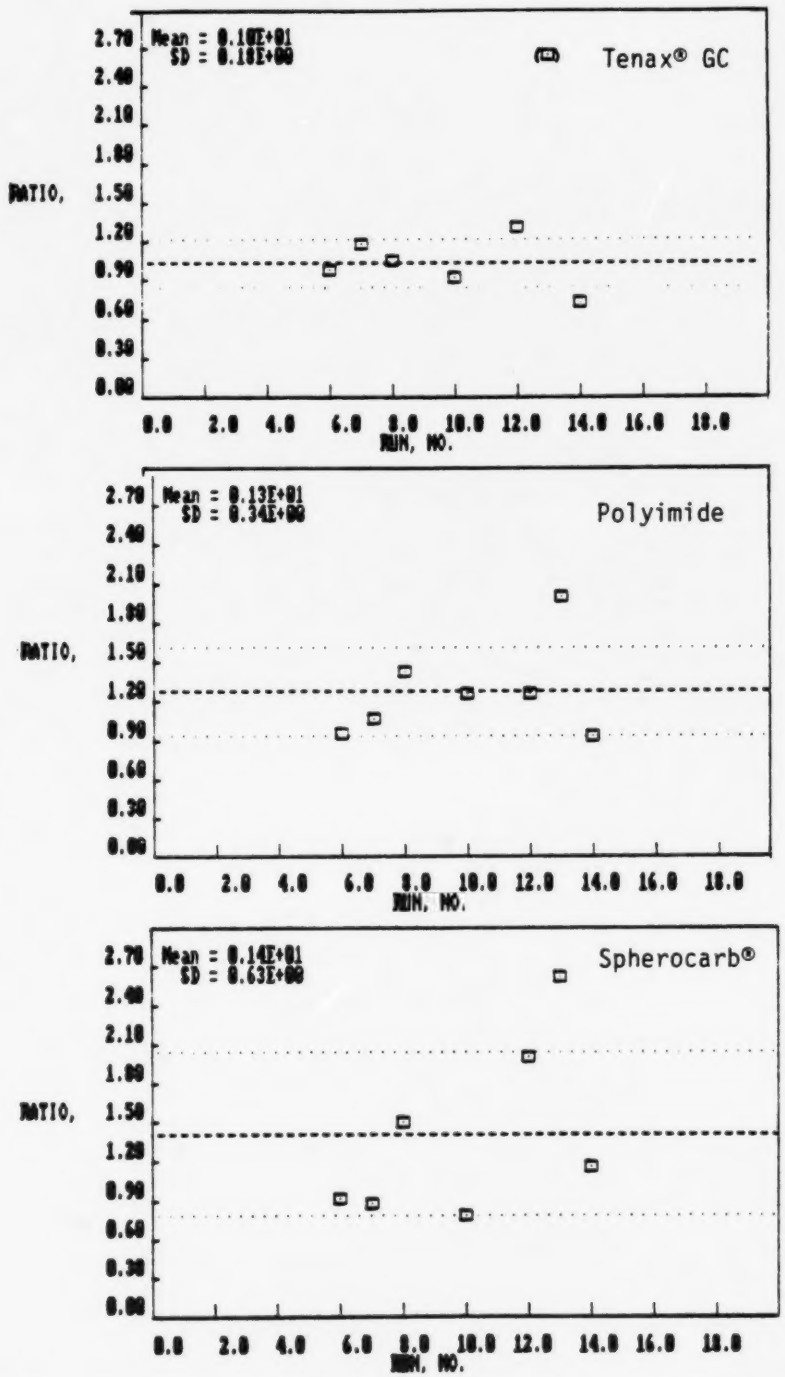

Figure 15. Scatterplot of benzene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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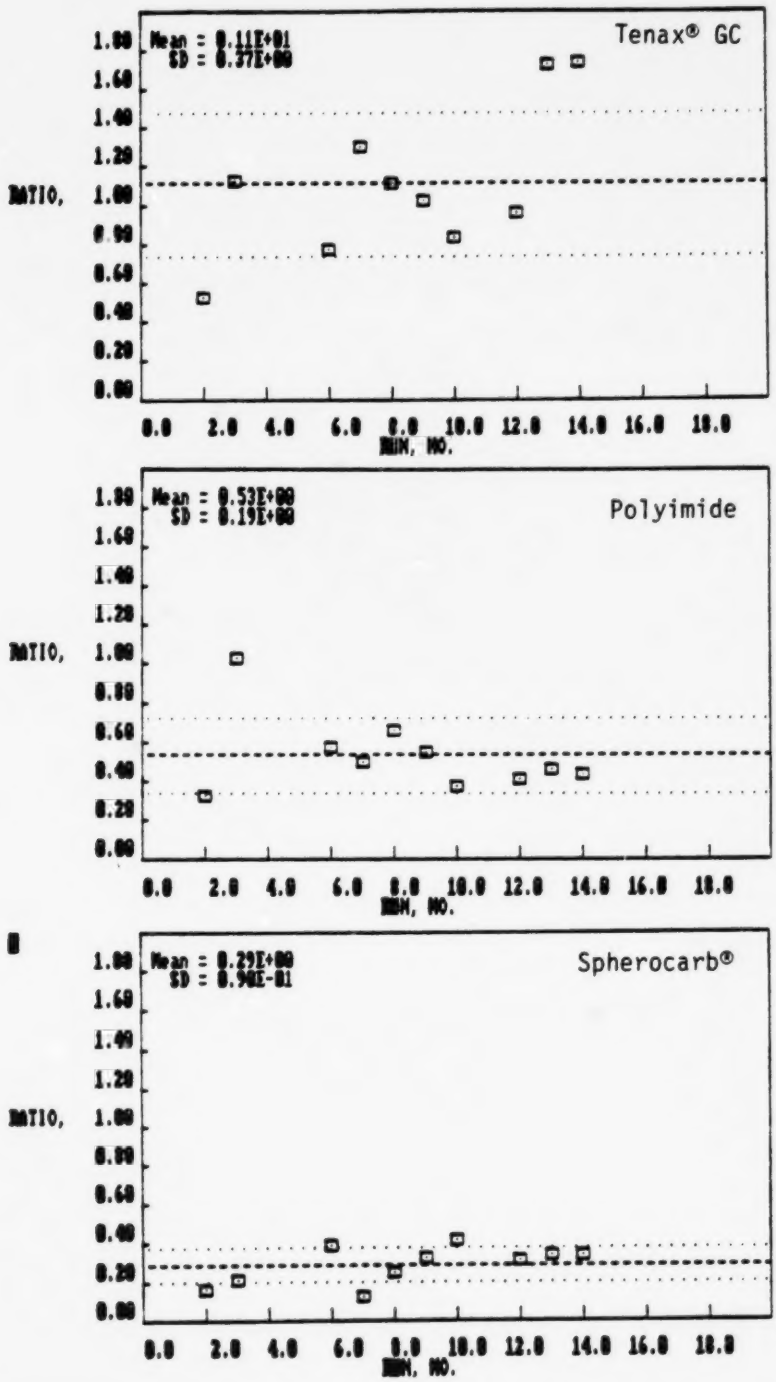

Figure 16. Scatterplot of tetrachloromethane data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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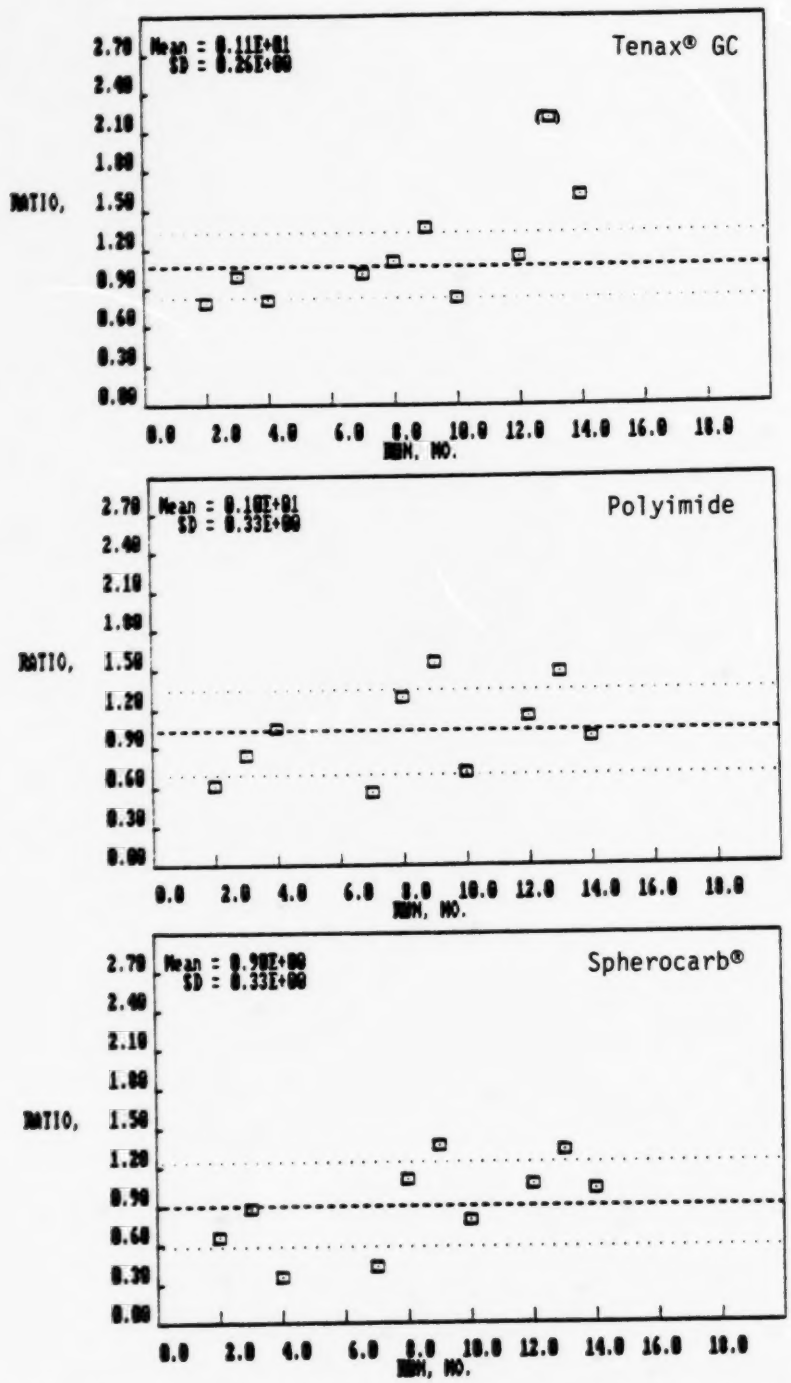

Figure 17. Scatterplot of trichloroethene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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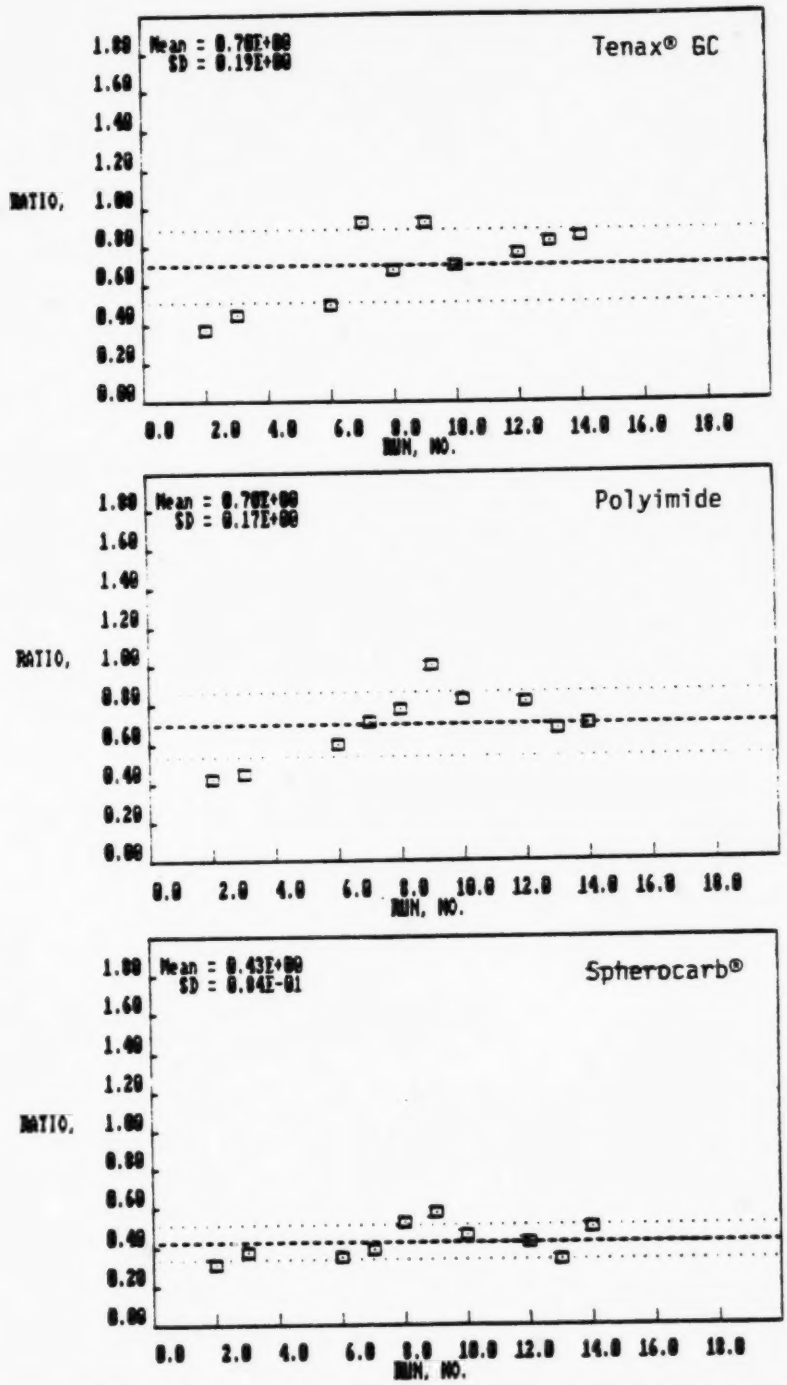

Figure 18. Scatterplot of toluene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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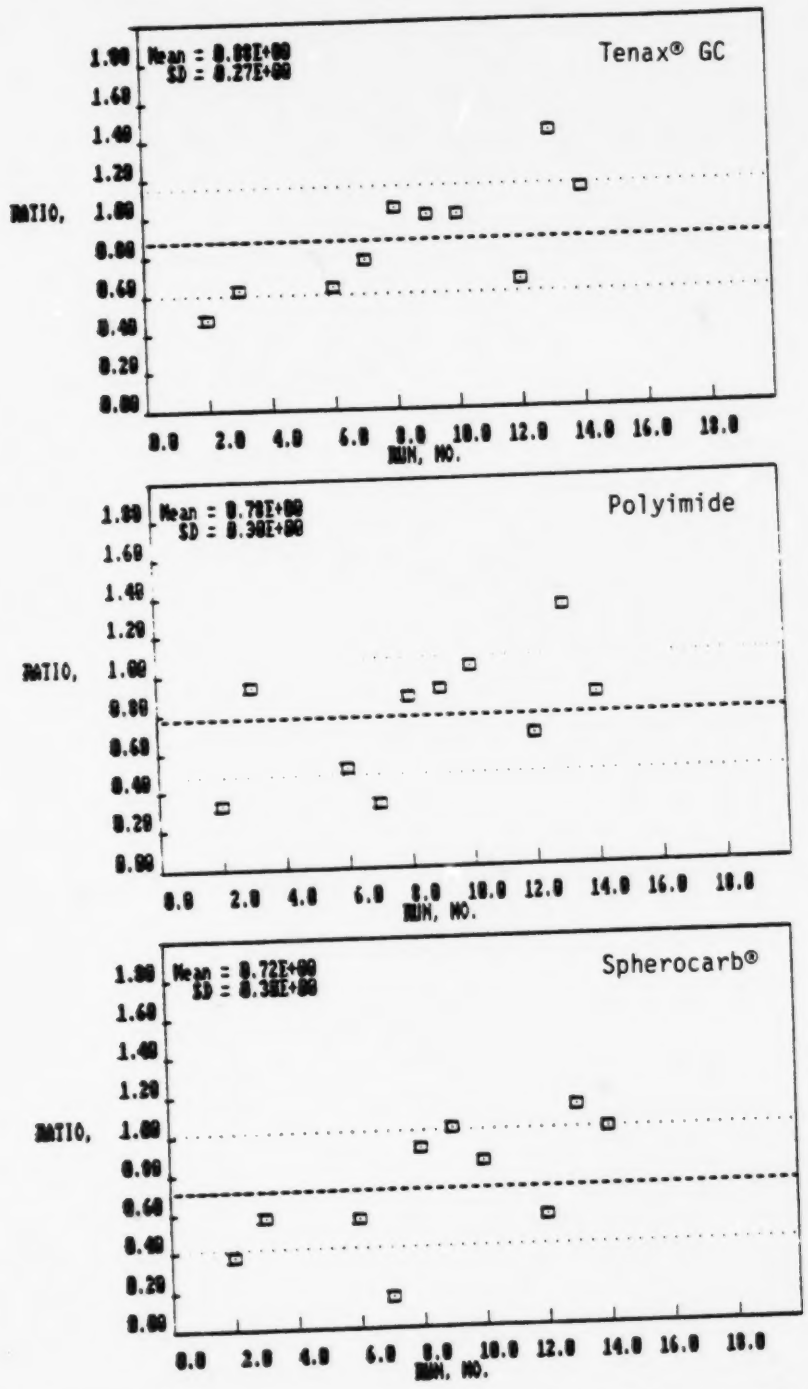

Figure 19. Scatterplot of tetrachloroethene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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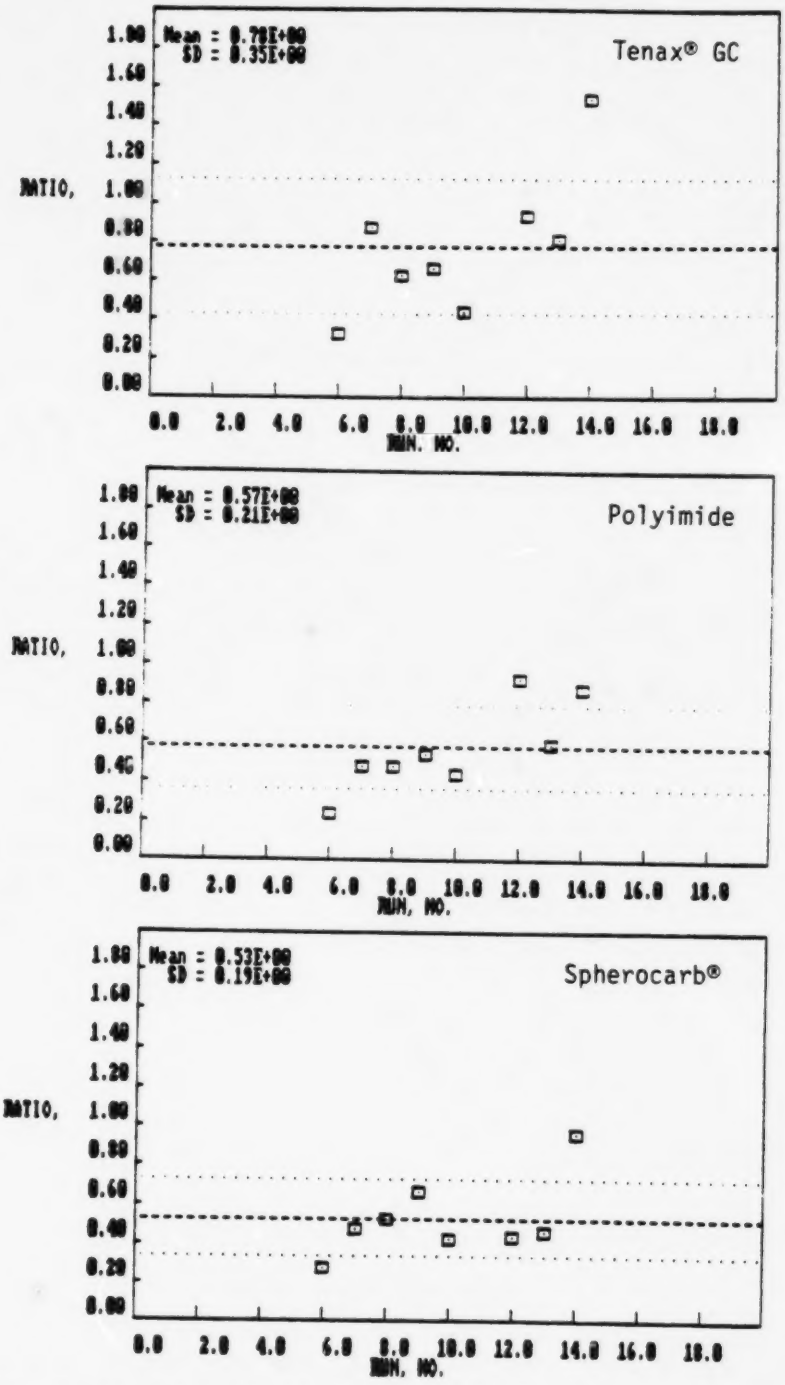

Figure 20. Scatterplot of chlorobenzene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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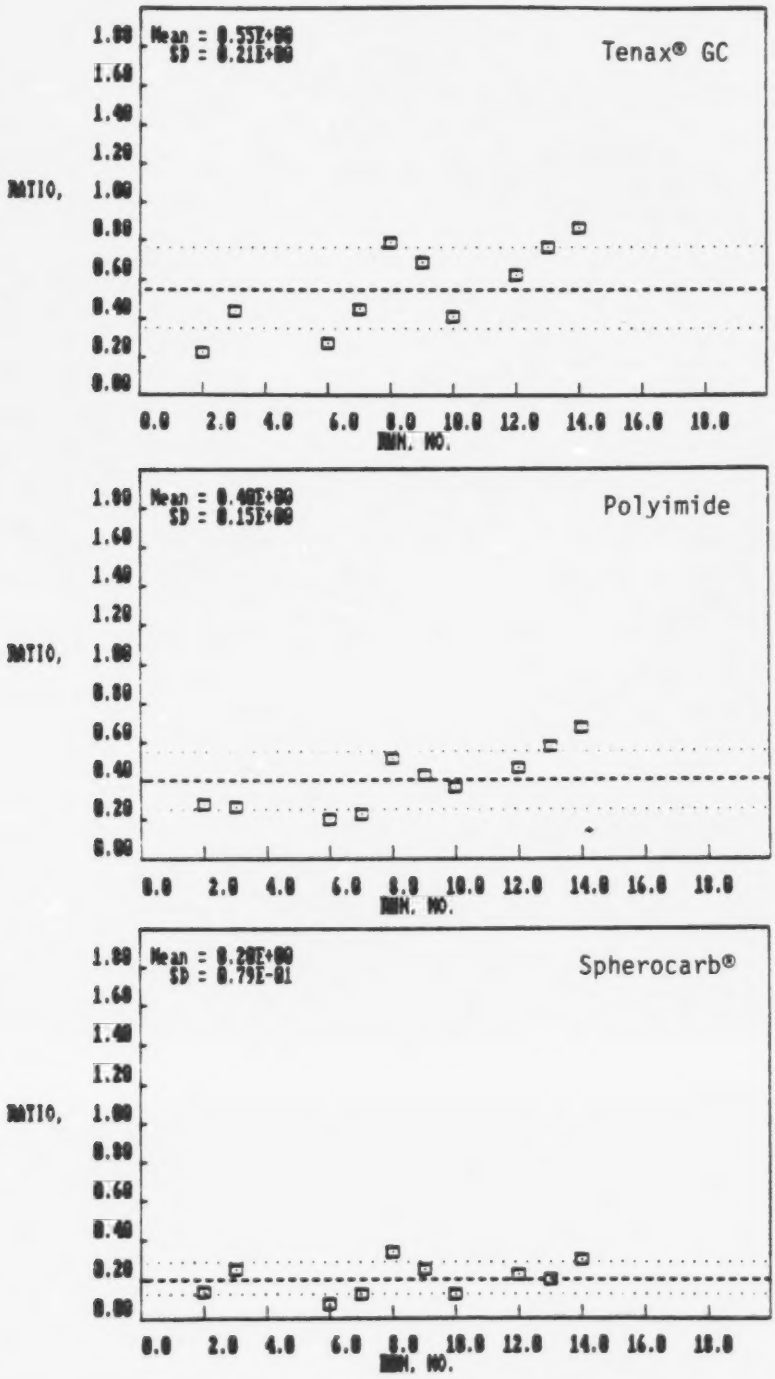

Figure 21. Scatterplot of 1,2-dimethylbenzene data points from individual runs. (Ratio is the concentration value for the adsorbent divided by the value obtained using cryogenic trapping/GC).

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1,1-dichloroethene artifactually high recovery, possibly due to dehydrohalogenation of 1,1,1-trichloroethane, was a major problem. Although low recoveries were anticipated for the other three compounds, on the basis of earlier work (5), the low recovery of 1,1-dichloroethene was not observed previously.

In spite of the problems discussed above, the data set provides important information for ambient air sampling. Inspection of Figures 7-21 reveals that, except for the major problem areas discussed above, the individual values generally agree with the value obtained by cryogenic trapping within a factor of two or better (i.e., 50 to 150% relative recovery). In view of the large temporal and spatial variability of organic pollutant concentrations observed in ambient air, this degree of agreement between methods is quite good. Furthermore, the health effects information and mathematical models used to assess the significance of the data are subject to much larger uncertainties.

Another encouraging aspect of the data set is the very low blank levels observed (Table 6). Our previous work with the open Tenax® tubes commonly employed in other laboratories (2, 8) resulted in much larger blank levels being obtained. In our hands the VOST style traps, which are positively sealed during storage and analysis (desorption), provide much lower blank levels.

One must recognize that the composition of the atmosphere being sampled may have a significant impact on the performance of any of the adsorbents, due to chemical and physical effects which are not fully understood. Therefore, the results obtained in this study may not be observed in all ambient air sampling situations. Ideally one should check the method performance, using the air sample of interest spiked with known quantities of the compounds to be determined. Since such experiments are expensive to conduct, it is usually not possible to obtain such data. For this reason any ambient air sampling data should be viewed as qualitative, or at least semiquantitative unless such data are provided. The use of directly spiked cartridges, or spiked clean air studies cannot substitute for such data.

PERFORMANCE FOR SPIKED HIGH PURITY AIR

As mentioned previously, Sampling Runs 4 and 11 utilized an audit cylinder containing several of the target compounds spiked into a high

purity air stream flowing through the same manifold as was employed for the ambient air experiments. Run 5 was a similar experiment using the calibration cylinder prepared at Battelle. Data for the audit cylinder are provided in Table 8. The absolute recoveries are not currently known since the cylinder concentrations have not been revealed to Battelle.

Data for the calibration cylinder are presented in Table 9. These data clearly indicate that cryogenic trapping provides the best recovery for each of the target compounds, except for the high (230%) recovery observed for 1,1,2-trichloro-1,2,2-trifluoroethane. The reasons for relatively low recoveries for the higher boiling compounds (e.g., toluene, chlorobenzene, and 1,2-dimethylbenzene) for all three adsorbents is not clear, since somewhat better recoveries were observed in the ambient air studies.

COMPARISON OF TENAX® DATA FROM BATTELLE AND EPA LABORATORIES

As discussed in the experimental section and companion report (7), sets of Tenax® samples were collected for analysis at both EPA and Battelle for selected runs, as a further check on method performance. Unfortunately, much of the data obtained from the analysis of the EPA cartridges were not useful because of high and variable levels of contamination in the blanks. Table 6 compares the data for Tenax® blanks achieved by Battelle and EPA. We attribute the lower Battelle values to the use of the "VOST" style cartridges, although other possible reasons for the observed difference exist. In some cases the EPA blank samples may have been subjected to considerable temperature cycles resulting from air shipment and airport storage prior to analysis. Also the blank samples were not handled according to EPA's standard operating procedure (SOP)(8). The SOP indicates that blanks are to be transported to the field site and returned to the laboratory for analysis without exposing the tubes to the sampling environment. Battelle personnel however, treated the adsorbent blanks in a fashion similar to the actual sampling tubes. Each blank tube was removed from its container along with the four sampling tubes. Each blank tube (i.e., one blank per four samples) was connected to the sampling system, sealed at the inlet and leak checked by activating the sampling pump. The blank tube was then immediately

TABLE 8. RESULTS FOR AUDIT CYLINDER SAMPLING EXPERIMENTS, ng/L

Compound	Run #4 (07/20/84)					Run #11 (08/03/84)			
	Cryogenic Sampling	Battelle Tenax	EPA Tenax	Polyimide	Spherocarb	Cryogenic Sampling	Battelle Tenax	Polyimide	Spherocarb
Chloroethene	9.4(1.3)[a]	0.7(0.28)	NA	6.6(0.92)	7.6(0.28)	9.4	ND	8.8(0.68)	6.3(1.5)
Trichloromethane	7.8(0.71)	8.1(0.28)	6.0	8.4(0.35)	3.9(0.35)	7.0(0.07)	7.5(1.1)	9.8(1.6)	5.0(1.2)
Benzene	18(1.4)	9.4(0.35)	11	12(2.0)	13	9.4	12(1.0)	19(3.2)	11(0.91)
Tetrachloromethane	21(2.0)	17(0)	19	24(4.9)	5.6(0.28)	15(0.06)	19(0.65)	33(5.6)	5.2(0.76)
Tetrachloroethene	8.0(0.71)	8.5(0.28)	7.7	9.1(0.42)	6.3(0.57)	5.6(0.07)	8.0(1.0)	9.4(0.92)	6.2(0.48)

a. Standard deviation for replicate analyses (quadruplicate for Tenax, triplicate for cryogenic sampling, and duplicate for polyimide and spherocarb) given in parenthesis.

TABLE 9. RESULTS FOR CALIBRATION CYLINDER SAMPLING EXPERIMENT, RUN #5, 07/20/84

Compound	Expected Concentration, ng/L	Percent Recovery[a]			
		Cryogenic Trapping	Tenax	Polyimide	Spherocarb
Chloroethene[b]	26	103	8.3	79	58
1,1-Dichloroethene[b]	17	112	55	91	76
Dichloromethane[b]	13	107	360	119	100
3-Chloropropene[b]	19	95	79	66	60
1,1,2-Trichloro-1,2,2,-Trifluoroethane[a]	34	230	47	60	123
Trichloromethane[b]	27	100	104	85	93
1,2-Dichloroethane[b]	24	120	96	40	63
1,1,1-Trichloroethane[b]	30	117	89	107	75
Benzene	15	93	73	115	105
Tetrachloromethane[b]	36	103	89	118	64
Trichloromethane	27	89	76	87	93
Toluene	18	90	50	65	52
Tetrachloroethene	34	118	65	68	76
Chlorobenzene	22	118	43	47	33
1,2-Dimethylbenzene	20	120	23	28	13

a. Average for duplicate samples.
b. Low volume (nominally 5 liters) Tenax value used for these compounds. Medium volume (nominally 10 liters) Tenax value used for all other compounds.

transferred to its original storage container. After the two hour sampling period had expired, the four sampling tubes were likewise returned to their storage containers. All tubes were returned to EPA within two weeks of collection. The sampling approach taken by Battelle is to be considered a modified distributive volume approach in which 5, 10, 10, and 20 liter volumes were used. Although an estimate of precision is obtained from the two 10 liter samples, the range of volumes is more restricted when compared to EPA's volumes of 10, 20, 40 and 80 liters. EPA has suggested that artifact formation may not be as easily detected with modified distributive volume approach. For the above reasons only the data points shown in Table 10 are useful for interlaboratory comparison. In general, good agreement is observed for these data points, both in terms of the Tenax® values and the values obtained by cryogenic trapping.

TABLE 10. DATA FOR INTERLABORATORY COMPARISON OF TENAX® METHODS

Compound	Run #	Concentration, ng/L		
		Cryogenic Sampling	Battelle Tenax®	EPA Tenax®
1,2-Dichloroethane	5	29	20(2.7)[a]	23(2.8)
Trichloroethene	5	24	20(6.5)	35(3.7)
Trichloroethene	7	4.6	5.8(1.5)[b]	3.2(0.64)
Trichloroethene	9	2.7(0.21)	4.2(1.0)	3.3(0.47)
Trichloroethene	10	4.2(0.03)	3.6(0.17)	3.9(0.29)
Trichloroethene	12	14(1.7)	17(2.2)	18(0.96)
Chlorobenzene	6	3.3	1.1(0.20)	2.6(0.09)
Chlorobenzene	7	2.5	2.4(0.21)[b]	2.6(0.36)
Chlorobenzene	8	2.6	3.2(0.57)	2.5(0.11)
Chlorobenzene	9	3.3	2.6(0.63)	2.7(0.03)
Chlorobenzene	10	4.3	2.0(0.15)	2.7(0.32)
Chlorobenzene	12	3.6	3.7(0.55)	2.6(0.18)
Tetrachloromethane	6	4.4	3.4(0.55)	2.1(0.36)
Tetrachloroethene	7	6.1	5.0(0.42)[b]	4.8(0.24)
Tetrachloroethene	10	4.8(0.03)	4.4(1.2)	5.2(0.62)
Tetrachloroethene	12	9.3	5.9(2.0)	5.4(0.07)

a. Standard deviation given in parentheses.
b. Twenty-liter sample not included in calculations for Run #7.

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APPENDIX

CONCENTRATION DATA FOR EXPERIMENTS

The Tenax®, polyimide, Spherocarb®, and cryogenic spiked data were from samples collected downstream of the spiking portion of the manifold. The cryogenic background data were from canister samples collected upstream of the spiking location. In the cryogenic data sets, several compounds are listed without standard deviation values. These compounds were only analyzed once due to software limitation in the analytical instrumentation. Details concerning this problem are given in the companion report (7).

TABLE A-1. CONCENTRATION DATA FOR RUN NUMBER 2, AMBIENT AIR 07/17/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.5	8.5	18.5	7.3	9.1		
Compound							
Chloroethene	ND[a]	ND	ND	1.1	1.4(1.15)[b]	NM[c]	NM
Acrylonitrile	1.5	0.3	0.4	1.5	0.7(0.14)	NM	NM
1,1-Dichloroethene	1.2	0.4	0.5	1.7	2.9(0.21)	NM	NM
Dichloromethane	24.0	11.5(2.12)	9.9	29.7	27.0(ND)	NM	NM
3-Chloropropene	2.2	0.9(0.21)	1.1	ND	1.3(0.21)	NM	NM
Trichlorotrifluoroethane	3.0	1.4(0.21)	1.0	1.5	5.5(0.64)	10.3(1.41)	9.4(1.27)
Trichloromethane	2.7	2.0(0.35)	2.4	0.5	1.4(0.99)	2.8(0.00)	0.9(0.00)
1,2-Dichloroethane	2.2	1.4(0.49)	2.0	1.1	1.1(0.61)	NM	NM
1,1,1-Trichloroethane	28.5	18.5(1.41)	22.5	11.1	12.3(5.30)	32.0(1.41)	31.0(1.41)
Benzene	4.8	3.9(0.49)	4.5	4.7	7.1(0.92)	NM	NM
Tetrachloromethane	2.6	2.0(0.14)	2.7	1.6	0.8(0.54)	4.9(0.14)	4.1(0.28)
Trichloroethylene	3.2	2.6(0.57)	3.1	2.0	2.2(0.64)	3.3(0.14)	0.7(0.14)
Toluene	6.9	5.9(1.41)	7.6	6.7	4.9(1.41)	15.8(0.00)	17.0(0.42)
Tetrachloroethene	3.0	2.5(0.64)	1.2	1.7	2.0(0.57)	5.2(0.14)	1.1(0.00)
Chlorobenzene	1.5	1.0(0.33)	1.4	1.0	1.0(0.23)	NM	NM
1,2-Dimethylbenzene	2.8	1.6(0.28)	1.3	1.9	1.0(0.17)	6.9(0.71)	5.0(0.42)

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-2. CONCENTRATION DATA FOR RUN NUMBER 3, AMBIENT AIR 07/19/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.6	9.4	18.2	7.7	9.5		
Compound							
Chloroethene	ND[a]	ND	ND	0.8	2.2(0.07)[b]	NM[c]	NM
Acrylonitrile	1.1	0.8(0.25)	0.5	1.4(0.2)	1.1(0.20)	NM	NM
1,1-Dichloroethene	1.8	1.4(0.14)	0.8	2.7(0.7)	7.7(1.27)	NM	NM
Dichloromethane	28.0	13.5(0.71)	5.9	25.0(2.83)	31.0(2.83)	NM	NM
3-Chloropropene	ND	2.3	1.1	1.6(0.42)	1.2	NM	NM
Trichlorotrifluoroethane	8.6	4.8(0.07)	1.9	5.7(1.63)	15.5(2.12)	NM	42.0
Trichloromethane	4.0	3.4(0.21)	2.9	3.3(0.28)	2.4(1.34)	4.7(0.14)	1.5
1,2-Dichloroethane	3.0	2.6(0.42)	1.9	2.0(0.21)	1.8(0.71)	NM	NM
1,1,1-Trichloroethane	78.0	57.5(10.6)	35.0	40.0(2.83)	37.5(10.61)	85.0(1.41)	81.0
Benzene	Saturated	Saturated	Saturated	Saturated	Saturated	Saturated	Saturated
Tetrachloromethane	6.0	5.2(0.92)	4.6	5.5(3.96)	1.1(0.47)	5.3(0.14)	1.2
Trichloroethylene	2.7	3.8(1.20)	4.3	3.2(1.84)	3.4(1.48)	3.8(0.14)	1.7
Toluene	12.0	10.4(2.33	13.0	10.4(2.33)	8.3(0.92)	22.5(0.42)	22.0
Tetrachloroethene	6.1	5.1(0.85)	3.2	4.8(0.28)	4.7(0.64)	8.1(0.14)	3.1
Chlorobenzene	2.3	2.0(0.49)	1.8	2.0(0.35)	2.0(0.28)	NM	NM
1,2-Dimethylbenzene	4.2	3.4(0.49)	2.4	2.0(0.21)	1.9(0.57)	7.7(0.14)	5.4

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-3. CONCENTRATION DATA FOR RUN NUMBER 4, AUDIT CYLINDER 07/20/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.5	9.1	18.2	8.3	9.0		
Compound							
Chloroethene	Sample Lost	0.7(0.28)	0.3	6.6(0.92)[b]	7.6(0.28)	9.4(1.27)	NM[c]
Acrylonitrile	"	ND[a]	ND	ND	ND	NM	NM
1,1-Dichloroethene	"	ND	ND	ND	ND	NM	NM
Dichloromethane	"	ND	ND	ND	ND	NM	NM
3-Chloropropene	"	ND	ND	ND	ND	NM	NM
Trichlorotrifluoroethane	"	3.4(1.20)	1.8	8.6(1.13)	8.5(0.49)	NM	NM
Trichloromethane	"	8.1(0.28)	5.9	8.4(0.35)	3.9(0.35)	7.8(0.71)	NM
1,2-Dichloroethane	"	ND	ND	ND	ND	NM	NM
1,1,1-Trichloroethane	"	ND	ND	ND	ND	NM	NM
Benzene	"	9.4(0.35)	7.9	12.4(1.95)	13.0(ND)	17.5(1.41)	NM
Tetrachloromethane	"	17.0	15.0	23.5(4.95)	5.6(0.28)	20.7(1.98)	NM
Trichloroethylene	"	ND	ND	ND	ND	NM	NM
Toluene	"	ND	ND	ND	ND	NM	NM
Tetrachloroethene	"	8.5(0.28)	6.4	9.1(0.42)	6.3(0.57)	8.0(0.71)	NM
Chlorobenzene	"	ND	ND	ND	ND	NM	NM
1,2-Dimethylbenzene	"	ND	ND	ND	ND	NM	NM

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-4. CONCENTRATION DATA FOR RUN NUMBER 5, CALIBRATION CYLINDER 07/24/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.5	9.4	18.1	8.2	9.0		
Compound							
Chloroethene	2.1	1.0(1.15)[a]	0.8	20.5(3.54)	15.0(1.41)	26.7	NM
Acrylonitrile	1.0	1.9(0.78)	2.7	1.6(2.26)	1.3(0.14)	NM[b]	NM
1,1-Dichloroethene	9.3	7.0(0 64)	5.5	15.5(3.54)	13.0(1.41	18.9	NM
Dichloromethane	46.7	10.0(4.31)	5.8	15.5(3.54)	13.0(1.41)	14.3	NM
3-Chloropropene	15.0	12.2(4.03)	11.0	12.5(3.54)	11.5(0.71)	18.2	NM
Trichlorotrifluoroethane	16.0	9.4(3.75)	7.0	20.5(2.12)	42.0(2.83)	79.4	NM
Trichloromethane	28.0	23.5(4.95)	23.0	23.0(1.41)	25.0(1.41)	27.1	NM
1,2-Dichloroethane	23.0	18.5(2.12)	18.0	9.5(13.44)	15.0(2.55)	28.9	NM
1,1,1-Trichloroethane	33.6	25.8(5.66)	24.9	32.0(0.00)	22.5(6.36)	34.8	NM
Benzene	12.7	10.9(1.41)	10.9	17.2(1.13)	15.8(1.24)	14.0	NM
Tetrachloromethane	32.0	26.0(5.66)	28.0	42.5(0.71)	23.0(5.66)	37.2	NM
Trichloroethylene	26.0	20.5(2.12)	13.0	23.5(0.71)	25.0(0.00)	23.7	NM
Toluene	10.9	9.0(0.35)	9.0	11.7(4.67)	9.4(0.92)	20.1(0.30)	NM
Tetrachloroethene	25.0	22.0(1.41)	15.0	23.0(4.24)	26.0(1.41)	40.0	NM
Chlorobenzene	11.8	9.4(0.35)	7.5	10.4(2.33)	7.2(5.37)	26.4	NM
1,2-Dimethylbenzene	5.1	4.6(0.28)	3.6	5.6(0 85)	2.6(0.28)	23.8(0.30)	NM

a. Value in parentheses is standard deviation for duplicate samples.
b. NM = Not Measured.

TABLE A-5. CONCENTRATION DATA FOR RUN NUMBER 6, AMBIENT AIR 07/26/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.6	8.7	18.3	7.0	9.1		
Compound							
Chloroethene	ND[a]	ND	ND	0.5(0.64)	2.0(0.21)[b]	2.5	ND
Acrylonitrile	0.3	0.4(0.16)	0.2	1.0(0.07)	0.7(0.06)	NM[c]	NM
1,1-Dichloroethene	2.4	1.2(0.14)	0.4	1.7(0.35)	16.0(2.83)	1.8	0.2
Dichloromethane	22.7	18.8(2.83)	12.4	23.5(2.12)	22.0(1.41)	32.0	30.0
3-Chloropropene	2.4	1.5(0.00)	0.6	4.5(0.42)	1.1(0.00)	2.5	ND
Trichlorotrifluoroethane	7.9	3.6(0.28)	1.8	3.4(2.33)	11.0(0.00)	16.3	9.5
Trichloromethane	11.0	8.9(0.92)	7.3	8.2(0.64)	8.1(1.56)	9.0	6.0
1,2-Dichloroethane	2.2	2.5(0.35)	1.8	1.5(0.28)	1.8(0.07)	2.4	0.3
1,1,1-Trichloroethane	60.6	57.8(2.83)	46.9	34.0(9.90)	38.0(4.24)	64.0	74.0
Benzene	41.7	47.8(5.66)	36.9	47.1(12.0)	45.3(2.12)	49.0	51.0
Tetrachloromethane	3.4	4.0(0.57)	2.9	2.5(0.64)	1.7(0.21)	4.4	0.9
Trichloroethylene	3.3	2.9(1.48)	1.5	3.8(0.28)	1.3(0.14)	3.6	1.3
Toluene	9.9	10.2(1.06)	10.0	11.8(3.11)	7.0(0.35)	20.3(0.60)	19.0(0.00)
Tetrachloroethene	3.6	3.5(0.14)	3.2	2.8(0.07)	3.1(0.00)	5.5	1.4
Chlorobenzene	0.9	1.1(0.00)	1.3	0.8(0.25)	0.9(0.00)	3.3	0.2
1,2-Dimethylbenzene	1.2	1.7(0.14)	1.1	1.2(0.28)	0.5(0.03)	6.0(0.40)	4.2(0.00)

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-6. CONCENTRATION DATA FOR RUN NUMBER 7, AMBIENT AIR 07/26/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.6	8.7	18.4	7.4	9.3		
Compound							
Chloroethene	ND[a]	ND	ND	ND	1.6(0.57)[b]	2.4	ND
Acrylonitrile	0.9	0.8(0.49)	0.1	1.3(0.88)	0.2(0.03)	NM[c]	NM
1,1-Dichloroethene	2.1	1.2(0.28)	0.3	1.5(0.21)	2.6(0.21)	1.9	ND
Dichloromethane	0.3	1.1(1.34)	0.1	2.9(0.21)	3.1(0.57)	3.1	1.9
3-Chloropropene	2.0	2.3(1.34)	0.7	3.8(2.97)	0.4(0.54)	1.9	ND
Trichlorotrifluoroethane	1.6	1.9(0.49)	0.4	1.2(0.21)	3.4(0.21)	24.6	1.5
Trichloromethane	1.3	1.0(0.03)	0.4	2.4(0.35)	2.1(0.28)	3.6	1.1
1,2-Dichloroethane	5.7	3.7(4.24)	1.0	1.5(0.28)	1.5(0.14)	2.6	ND
1,1,1-Trichloroethane	8.9	5.6(0.00)	1.3	2.3(0.57)	1.4(0.14)	4.5	3.2
Benzene	8.9	5.7(0.99)	1.1	5.1(0.92)	4.3(0.00)	4.8	NM
Tetrachloromethane	5.2	3.6(0.7)	1.1	2.0(0.07)	0.5(0.10)	4.0	0.9
Trichloroethylene	6.8	4.7(0.21)	2.0	2.6(0.00)	2.0(0.21)	4.6	0.8
Toluene	10.9	10.6(3.39)	2.8	8.5(4.95)	4.7(0.07)	12.0(0.71)	5.1
Tetrachloroethene	5.3	4.7(1.56)	0.8	2.0(0.07)	1.0(1.34)	6.1	1.0
Chlorobenzene	2.5	2.2(0.78)	0.3	1.2(0.54)	1.2(0.00)	2.5	0.2
1,2-Dimethylbenzene	2.9	2.0(0.28)	0.4	1.0(0.92)	0.6(0.07)	4.5(0.07)	2.6

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-7. CONCENTRATION DATA FOR RUN NUMBER 8, AMBIENT AIR 07/30/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.4	9.2	18.4	7.0	9.6		
Compound							
Chloroethene	0.3	ND[a]	ND	0.3	2.5(0.06)[b]	2.3	ND
Acrylonitrile	0.6	0.3(0.20)	0.3	2.0	1.2(0.08)	NM[c]	NM
1,1-Dichloroethene	0.8	0.5(0.24)	0.4	1.3	5.3(0.64)	1.7	ND
Dichloromethane	11.7	10.9(0.74)	9.0	12.8	13.2(0.33)	12.5	10.7
3-Chloropropene	1.5	1.1(0.40)	0.8	3.5	0.7(0.08)	2.3	ND
Trichlorotrifluoroethane	1.5	0.7(0.16)	0.6	1.0	3.7(0.23)	8.5(0.07)	1.9
Trichloromethane	4.3	3.3(0.35)	3.6	3.5	2.9(0.13)	4.1(0.07)	1.5
1,2-Dichloroethane	2.8	2.5(0.25)	2.7	2.5	2.5(0.08)	2.5	ND
1,1,1-Trichloroethane	11.4	9.5(1.70)	11.2	6.6	4.0(0.24)	9.2(0.07)	6.5
Benzene	4.7	4.2(0.23)	4.6	5.7	6.0(1.09)	4.0	4.0
Tetrachloromethane	4.0	2.5(0.24)	2.7	2.4	0.9(0.24)	3.6(0.06)	0.9
Trichloroethylene	4.7	4.1(0.03)	4.3	4.8	4.1(0.17)	3.7(0.21)	0.8
Toluene	10.2	8.2(0.74)	7.9	9.4	6.3(0.17)	12.1(0.03)	10.4(0.04)
Tetrachloroethene	5.6	5.0(0.47)	5.3	4.2	4.5(0.49)	4.8(0.04)	1.0
Chlorobenzene	3.8	3.0(0.14)	2.7	2.3	2.5(0.01)	2.6	0.2
1,2-Dimethylbenzene	5.5	4.2(0.17)	3.4	2.7	1.8(0.10)	5.3(0.18)	3.2(0.01)

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-8. CONCENTRATION DATA FOR RUN NUMBER 9, AMBIENT AIR 07/31/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.6	8.6	19.0	6.7	8.2		
Compound							
Chloroethene	ND[a]	ND	ND	ND	3.0(0.42)[b]	2.7	0.0
Acrylonitrile	1.1	0.3(0.59)	0.3	1.1(1.56)	1.4(0.79)	NM[c]	NM
1,1-Dichloroethene	3.1	1.0(0.20)	0.4	0.9(1.32)	14.2(4.16)	2.0	ND
Dichloromethane	49.8	23.6(0.79)	11.3	4.70(1.47)	50.2(7.21)	59.2	59.7
3-Chloropropene	3.6	1.6(0.23)	1.0	4.5(0.40)	1.2(0.34)	2.3	0.6
Trichlorotrifluoroethane	15.0	6.8(1.53)	3.0	7.5(1.12)	16.7(2.88)	15.3(2.26)	11.6
Trichloromethane	7.0	5.3(0.34)	4.0	5.5(0.51)	4.2(0.82)	4.7(0.06)	2.4
1,2-Dichloroethane	4.3	3.3(0.24)	3.0	3.0(0.37)	3.3(0.31)	4.0	2.6
1,1,1-Trichloroethane	38.6	26.4(1.29)	23.6	17.1(3.14)	11.5(0.57)	22.0(2.26)	22.6
Benzene	No Data	No Data	No Data	No Data	No Data	4.4	4.1
Tetrachloromethane	4.1	3.6(0.01)	2.5	2.2(0.44)	1.3(0.10)	4.0(0.00)	0.8
Trichloroethylene	5.4	3.7(0.13)	3.6	4.2(0.41)	3.7(0.48)	2.7(0.21)	0.5
Toluene	15.3	14.5(0.79)	14.7	15.2(3.93)	8.7(0.24)	14.6(0.14)	13.4(0.03)
Tetrachloroethene	4.3	3.7(0.44)	1.6	3.4(0.20)	3.8(0.54)	3.7(0.00)	0.5
Chlorobenzene	3.3	2.2(0.11)	2.2	1.8(0.34)	2.2(0.14)	3.3	ND
1,2-Dimethylbenzene	4.1	3.3(0.06)	2.6	2.0(0.45)	1.2(0.14)	4.8(0.20)	3.2(0.23)

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-9. CONCENTRATION DATA FOR RUN NUMBER 10, AMBIENT AIR 08/02/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.8	9.3	18.7	7.4	9.8		
Compound							
Chloroethene	0.8	ND[a]	ND	ND	1.3(0.45)[b]	2.7	NM[c]
Acrylonitrile	1.0	0.7(0.03)	0.4	1.5(0.18)	0.7(0.65)	NM	NM
1,1-Dichloroethene	7.5	0.9(0.00)	0.4	0.7(0.96)	9.8(2.28)	1.8	ND
Dichloromethane	26.4	17.5(1.50)	10.3	20.1(0.92)	30.0(0.74)	33.0	42.5
3-Chloropropene	2.5	2.0(0.27)	0.9	3.0(0.06)	0.9(0.03)	NM	NM
Trichlorotrifluoroethane	4.3	2.3(0.37)	1.2	0.5(0.06)	8.7(0.54)	11.3(0.10)	6.1
Trichloromethane	1.7	3.9(0.20)	3.1	2.7(0.71)	2.5(0.04)	3.1(0.03)	0.8
1,2-Dichloroethane	2.9	2.8(0.06)	2.2	1.6(0.21)	1.9(0.06)	2.9	0.1
1,1,1-Trichloroethane	22.2	33.0(0.34)	23.3	10.3(2.43)	11.9(2.53)	28.6(4.24)	28.0
Benzene	15.4	10.9(0.06)	11.0	9.5(1.41)	14.7(0.31)	12.2	10.8
Tetrachloromethane	3.1	3.7(0.28)	3.2	1.4(0.34)	1.5(0.37)	3.7(0.03)	0.8
Trichloroethylene	3.8	3.5(0.11)	3.5	3.0(0.08)	3.3(0.58)	4.2(0.03)	0.7
Toluene	13.7	12.3(0.31)	14.1	13.8(1.37)	7.8(0.57)	16.6(0.05)	15.5(0.03)
Tetrachloroethene	5.3	4.8(0.14)	3.0	4.9(0.48)	4.1(0.17)	4.8(0.03)	0.8
Chlorobenzene	2.0	1.9(0.11)	2.2	1.9(0.06)	1.3(0.14)	4.3	ND
1,2-Dimethylbenzene	3.6	2.8(0.23)	3.0	2.4(0.42)	0.9(0.21)	6.7(0.07)	5.6(0.08)

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-10. CONCENTRATION DATA FOR RUN NUMBER 11, AUDIT CYLINDER 08/03/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	5.1	9.4	18.4	7.1	9.3		
Compound							
Chloroethene	ND[a]	0.1(0.14)[b]	0.1	8.8(0.68)	6.3(1.53)	9.4	NM[c]
Acrylonitrile	ND	0.0(0.01)	ND	0.1(0.18)	ND	NM	NM
1,1-Dichloroethene	ND	0.0	ND	ND	ND	NM	NM
Dichloromethane	ND	ND	ND	18.4(5.71)	ND	NM	NM
3-Chloropropene	ND	0.0	ND	ND	ND	NM	NM
Trichlorotrifluoroethane	0.2	0.0	ND	ND	ND	NM	NM
Trichloromethane	7.0	7.5(1.10)	7.1	9.8(1.64)	5.0(1.24)	7.0(0.07)	NM
1,2-Dichloroethane	ND	0.0(0.06)	0.1	0.1(0.01)	ND	NM	NM
1,1,1-Trichloroethane	0.8	0.3(0.06)	0.3	0.9(0.17)	0.1(0.14)	0.5(0.07)	NM
Benzene	11.2	11.5(1.02)	11.6	18.6(3.22)	11.4(0.91)	9.4	NM
Tetrachloromethane	17.4	18.6(0.65)	18.5	33.1(5.64)	5.2(0.76)	14.9(0.06)	NM
Trichloroethylene	0.9	0.5(0.11)	0.5	0.9(0.23)	0.5(0.09)	NM	NM
Toluene	3.4	3.6(0.04)	3.1	4.3(0.91)	2.5(0.01)	2.7(0.06)	NM
Tetrachloroethene	6.6	8.0(1.00)	8.1	9.4(0.92)	6.2(0.48)	5.6(0.07)	NM
Chlorobenzene	0.3	0.3(0.08)	0.3	0.6(0.06)	0.3(0.03)	NM	NM
1,2-Dimethylbenzene	1.1	1.0(0.01)	1.0	1.3(0.33)	0.4(0.03)	NM	NM

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-11. CONCENTRATION DATA FOR RUN NUMBER 12, AMBIENT AIR 07/06/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.6	9.4	18.4	7.2	9.2		
Compound							
Chloroethene	ND[a]	ND	ND	ND	1.2(0.28)[b]	3.1	NM[c]
Acrylonitrile	1.6	1.2(0.03)	0.7	2.0(0.06)	1.4(0.03)	NM	NM
1,1-Dichloroethene	1.7	1.2(0.23)	0.6	1.3(0.08)	8.8(1.07)	2.2	NM
Dichloromethane	9.9	11.5(7.67)	4.2	34.6(11.50)	22.4(0.71)	22.6	NM
3-Chloropropene	1.8	1.7(0.40)	1.1	ND	0.3(0.10)	2.1	NM
Trichlorotrifluoroethane	5.6	3.0(0.06)	1.6	1.1(0.58)	9.7(0.72)	14.6(0.10)	6.7(0.04)
Trichloromethane	4.6	3.7(0.41)	3.3	2.9(0.01)	2.2(0.57)	4.7(0.04)	0.8(0.07)
1,2-Dichloroethane	3.4	3.3(0.57)	3.3	2.1(0.37)	2.6(0.25)	4.4	NM
1,1,1-Trichloroethane	25.1	22.2(2.25)	19.5	10.3(0.82)	7.1(0.17)	19.5(0.10)	17.8(0.10)
Benzene	9.1	7.2(0.85)	9.7	6.9(0.96)	10.8(0.49)	5.5	NM
Tetrachloromethane	4.7	3.8(0.28)	4.7	2.0(0.00)	1.5(0.04)	4.9(0.04)	1.1(0.07)
Trichloroethylene	19.3	15.9(1.80)	15.1	15.7(1.90)	15.2(0.78)	14.3(1.70)	12.5(0.07)
Toluene	16.5	15.8(2.15)	16.6	17.1(2.43)	9.1(0.07)	21.1(0.15)	18.8(0.07)
Tetrachloroethene	7.7	6.1(0.57)	3.8	6.2(0.54)	5.2(0.24)	9.3	2.3(0.07)
Chlorobenzene	4.3	3.4(0.42)	3.3	3.3(0.59)	2.5(0.10)	3.6	NM
1,2-Dimethylbenzene	6.9	5.0(0.44)	3.7	3.7(0.79)	1.7(0.01)	7.9(0.07)	4.6(0.00)

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.

TABLE A-12. CONCENTRATION DATA FOR RUN NUMBER 13, AMBIENT AIR 08/07/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.5	8.5	18.1	7.0	9.1		
Compound							
Chloroethene	0.1	0.1(0.04)[a]	0.1	ND[b]	1.5(0.42)	2.5	NM[c]
Acrylonitrile	2.3	1.3(0.11)	0.8	2.0(0.37)	1.4(1.10)	NM	NM
1,1-Dichloroethene	2.0	1.3(0.03)	0.7	0.6(0.78)	6.2(0.28)	5.1	NM
Dichloromethane	22.6	12.7(3.76)	5.8	15.9(1.09)	14.5(1.56)	17.5	NM
3-Chloropropene	3.4	2.1(0.38)	1.3	4.3(0.51)	0.7(0.68)	7.3	NM
Trichlorotrifluoroethane	3.7	2.7(0.11)	1.4	0.5(0.45)	7.8(0.79)	11.8(0.04)	6.3(0.07)
Trichloromethane	7.2	5.7(0.14)	4.2	4.0(0.51)	3.2(1.27)	4.6(0.06)	4.5(0.13)
1,2-Dichloroethane	4.5	3.7(0.01)	3.0	2.2(0.45)	2.7(0.28)	3.8	NM
1,1,1-Trichloroethane	20.2	15.6(0.57)	12.3	4.6(0.85)	4.3(1.92)	12.4(2.12)	10.4(0.35)
Benzene	10.6	8.5(1.98)	5.9	6.4(0.24)	8.4(0.17)	3.2	NM
Tetrachloromethane	8.6	6.0(14.0)	3.9	2.3(0.38)	1.7(0.79)	5.0(0.06)	2.0(0.03)
Trichloroethylene	6.5	6.0(0.54)	4.7	4.0(0.47)	3.6(1.13)	2.7(0.04)	1.1(0.00)
Toluene	20.0	18.2(1.81)	17.2	15.3(3.21)	7.5(3.48)	21.8(0.03)	20.8(0.11)
Tetrachloroethene	10.6	8.1(0.23)	4.7	7.5(0.51)	6.4(0.93)	5.7(0.01)	1.9(0.07)
Chlorobenzene	5.8	4.6(0.03)	3.7	3.4(0.68)	2.6(0.48)	3.2	NM
1,2-Dimethylbenzene	9.2	6.8(0.18)	5.1	5.1(0.91)	1.8(0.47)	8.9(1.00)	6.1(0.04)

a. Value in parentheses is standard deviation for duplicate samples.
b. ND = Not Detected.
c. NM = Not Measured.

TABLE A-13. CONCENTRATION DATA FOR RUN NUMBER 14, AMBIENT AIR 08/09/84, ng/L

	Low Tenax®	Medium Tenax®	High Tenax®	Polyimide	Spherocarb®	Cryogenic Spiked	Cryogenic Background
Average Sampling Volume, Liters	4.6	8.6	19.8	6.8	8.9		
Compound							
Chloroethene	0.2	ND[a]	Sample Lost	ND	ND	2.5	1.8
Acrylonitrile	1.9	1.2(0.01)[b]	"	1.8(0.37)	2.2	NM[c]	NM
1,1-Dichloroethene	2.6	1.4(0.20)	"	1.0(0.04)	10.3	6.1	4.6
Dichloromethane	24.3	16.7(1.33)	"	11.8(0.54)	25.8	31.9	25.8
3-Chloropropene	4.4	2.6(0.03)	"	2.4(0.23)	2.9	8.5	7.2
Trichlorotrifluoroethane	5.0	2.6(0.01)	"	0.9(0.25)	13.9	12.2(2.69)	7.3
Trichloromethane	5.9	5.1(0.28)	"	3.0(0.85)	2.0	4.8(0.31)	5.4
1,2-Dichloroethane	4.3	3.8(0.01)	"	2.2(0.03)	2.8	3.4	3.0
1,1,1-Trichloroethane	34.0	30.4(1.80)	"	9.7(1.44)	9.8	18.8(2.97)	19.4
Benzene	16.0	11.4(2.55)	"	7.6(0.91)	9.5	8.1	7.5
Tetrachloromethane	7.1	5.0(2.90)	"	1.8(0.18)	1.4	4.1(0.08)	3.0
Trichloroethylene	10.1	8.2(0.54)	"	5.0(0.40)	5.3	5.1(0.01)	3.4
Toluene	19.8	17.2(1.13)	"	14.4(3.56)	10.3	20.1(0.90)	17.8(0.06)
Tetrachloroethene	9.2	8.3(0.14)	"	6.4(1.81)	7.4	7.3	4.0(0.08)
Chlorobenzene	5.6	4.3(0.06)	"	3.2(0.49)	2.7	2.8	0.7(0.08)
1,2-Dimethylbenzene	9.6	6.9(0.72)	"	5.5(0.59)	2.4	8.0(1.40)	6.3(0.08)

a. ND = Not Detected.
b. Value in parentheses is standard deviation for duplicate samples.
c. NM = Not Measured.